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Document Number:

3) II-D-2

Docket Number:

A-90-16

Docket A-90-16
II-D-2

BEFORE THE
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

IN RE APPLICATION FOR A FUEL ADDITIVE WAIVER FILED BY ETHYL CORPORATION UNDER § 211(f)(4) OF THE CLEAN AIR ACT	)

RECEIVED
MAY 10 1990
EPA AIR DOCKET

APPENDICES TO THE WAIVER APPLICATION
FOR THE HiTEC 3000 PERFORMANCE ADDITIVE

VOLUME ONE

APPENDICES 1, 2A, 2B AND 2C

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May 9, 1990

HiTEC 3000 WAIVER APPLICATION APPENDICES

Appendix No.

VOLUME ONE

1. Fleet Test Protocol

2. Statistical Analyses of the HiTEC 3000 Additive Test Program Data

   2A - Statistical Analysis of Automotive Exhaust Emissions in Support of Ethyl's HiTEC 3000 Fuel Waiver Application (Systems Applications, Inc. May 4, 1990).

   2B - Analysis of Ethyl Emission Test Data (Roberson Pitts, Inc. April 1990)

   2C - Instantaneous Effects Analysis

VOLUME TWO

3. Durability Testing, Materials Compatibility Testing, Evaporative Emissions, Driveability, and Particulate Emissions

4. Effects of the HiTEC 3000 Performance Additive on Hydrocarbon Species in Automobile Exhaust Emissions

5. Use of the Urban Airshed Model to Assess the Effects of HiTEC 3000 Performance Additive on Urban Air Quality (Systems Applications, Inc. May 4, 1990)

VOLUME THREE

6. Additional Environmental, Economic and Energy Benefits Associated with Use of the HiTEC 3000 Additive

7. Total Pollutant Reductions

8. Health and Environmental Implications of Use of HiTEC 3000 as a Fuel Additive

9. Compilation of Scientific Studies that Provide Additional Support for the HiTEC 3000 Additive Waiver Application

MILEAGE ACCUMULATION ROUTE

LOCATION OF TURN	LOCATION OF SPEED CHANGE	ODOMETER	SPEED LIMIT (MPH)
	ENTERING BUSINESS AREA	52.1	25
SHIAWASSEE ROAD EAST		52.7	25
	TUCK ROAD	54.2	35
	INKSTER	55.9	30
8-MILE ROAD EAST		57.4	45
BERG ROAD NORTH		58.8	30
CIVIC CENTER DRIVE WEST		61.4	35
11-MILE ROAD WEST		62.3	45
FARMINGTON ROAD SOUTH		66.6	45
	10-MILE ROAD	67.6	25
SHIAWASSEE ROAD EAST		67.9	25
ORCHARD LAKE ROAD SOUTH		68.7	30
GRAND RIVER EAST		69.1	35
	EXIT BUSINESS AREA	69.6	45
INKSTER ROAD SOUTH		71.3	40
7-MILE ROAD EAST		72.1	35
	EVERGREEN	76.1	30
GREENFIELD ROAD SOUTH		78.1	35
	ENTER BUSINESS AREA	80.4	30
	EXIT BUSINESS AREA	81.1	35
WARREN ROAD WEST		84.1	35
	ANN ARBOR TRAIL	87.4	40
NEWBURGH ROAD SOUTH		95.2	40

MILEAGE ACCUMULATION ROUTE

LOCATION OF TURN	LOCATION OF SPEED CHANGE	ODOMETER	SPEED LIMIT (MPH)
FORD ROAD WEST		95.9	45
I-275 NORTH		97.7	55
8-MILE ROAD EAST		105.7	50
	FARMINGTON ROAD	107.7	40
FARMINGTON ROAD NORTH		111.6	40
9-MILE ROAD WEST		112.6	40
	HAGGERTY	115.5	35
MEADOWBROOK ROAD NORTH		116.6	30
	10-MILE ROAD	117.6	40
GRAND RIVER WEST		118.4	50
	ENTERING BUSINESS AREA	119.1	40
NOVI ROAD NORTH		119.3	30
	NORTH OF 96	119.7	40
	12-MILE ROAD	120.1	30
EAST WALLED LAKE DRIVE NORTH		121.4	30
	14-MILE ROAD	122.6	25
PONTIAC TRAIL NORTH/EAST		123.3	35
	SOUTH COMMON ROAD	124.1	40
	WELCH ROAD	125.1	45
	ENTERING RESIDENTIAL AREA	128.7	35
ORCHARD LAKE ROAD NORTH		130.6	35
MIDDLEBELT ROAD SOUTH		133.7	40
	LONG LAKE ROAD	135.5	45

MILEAGE ACCUMULATION ROUTE

LOCATION OF TURN	LOCATION OF SPEED CHANGE	ODOMETER	SPEED LIMIT (MPH)
LONE PINE ROAD EAST		136.5	35
INKSTER ROAD SOUTH		137.5	35
WELLINGTON NORTHEAST		141.3	25
FRANKLIN ROAD NORTH		142.5	35
	EXIT BUSINESS AREA	143.2	40
QUARTON ROAD EAST		144.7	40
TELEGRAPH ROAD SOUTH		145.6	50
QUARTON ROAD EAST		145.9	35
CRANBROOK ROAD SOUTH		148.3	25
	MAPLE	149.3	30
	14-MILE ROAD	150.4	25
	CRANBROOK BECOMES EVERGREEN	151.4	35
	12-MILE ROAD	152.4	40
CIVIC CENTER DRIVE WEST		153.9	35
11-MILE ROAD WEST		156.8	45
INKSTER ROAD SOUTH		158.2	35
8-MILE ROAD WEST		161.1	40
MERRIMAN ROAD SOUTH		163.1	40
I-96 EXPRESSWAY WEST		167.1	55
LEVAN ROAD SOUTH		168.6	40
COMMERCE STREET WEST		169.1	25
ECS LABORATORIES (FINISH)		169.4	

Attachment 1-6

ATL EPA MILEAGE ACCUMULATION SCHEDULE *

The schedule consists basically of 11 laps of a 3.0 mile course. The basic vehicle speed for each lap is listed below:

Lap	Speed MPH
1	40
2	30
3	40
4	40
5	35
6	30
7	35
8	45
9	35
10	55
11	55

During each of the first nine (9) laps there are 3 stops with 15 second idle. Normal accelerations and decelerations are used. In addition, there are 4 light decelerations each lap from the base speed to 20 mph followed by light accelerations to the base speed.

The 10th lap is to be driven at a constant speed of 55 mph after a normal acceleration from the stop following lap 9 and proceeding to a normal deceleration to a stop before lap 11.

The 11th lap is begun with a wide open throttle acceleration to 55 mph, a fast deceleration to a stop, and two (2) subsequent wide open throttle accelerations and fast decelerations at evenly spaced intervals in the 3.0 mile lap.

* As Adapted to Bendix Track, South Bend

Attachment 1-7

EMISSION TESTING SCHEDULE FOR FIRST 1000 MILES

ALL CARS TESTED AT ECS LABORATORY

ODOMETER	DESCRIPTION
0	A1. Check car for all emission related equipment hook-ups. Record any changes from car in the "rec'd condition" section of the vehicle log book.
	A2. Record catalyst converter numbers.
	A3. Drain fuel and refill with Howell EEE emission fuel.
	A4. Run CVS-FTP emission prep cycle.
	A5. (Day 1) Run FTP emission cycle test. (Maxi CVS data).
	A6. (Day 2) Run FTP emission cycle test. (Maxi CVS data).
	A7. (Day 3) Obtain 3rd FTP if HC, CO, NOx variability is unacceptable.
	A8. Begin mileage accumulation on EPA type durability cycle.
1000	B1. Perform steps A3 through A7 - hold cars for grouping.
	B2. Group cars into sets of three for each model and fill fuel tanks with proper fuel (three cars on Howell EEE fuel, with the remaining cars on Howell EEE fuel plus 0.03125 grams manganese per gallon as the HiTEC 3000 additive).

Attachment 1-8

FTP EMISSION TESTING SCHEDULE, 1000 TO 75,000 MILES
AT ECS AND ATL

ODOMETER	DESCRIPTION
1000	A1. Group cars into sets of three for each model and identify proper fuel for each car (three cars on Howell EEE fuel and three cars on Howell EEE fuel plus 0.03125 gr. manganese per gallon as the HiTEC 3000 additive).
	A2. Drain fuel and refill with Howell EEE emission fuel.
	A3. Run CVS-FTP emission prep cycle.
	A4. (Day 1) Run FTP emission cycle test. (Maxi CVS data).
	A5. (Day 2) Run FTP emission cycle test. (Maxi CVS data).
	A6. (Day 3) Obtain 3rd FTP if HC, CO, NOx variability is unacceptable.
	A7. Begin mileage accumulation on EPA type durability cycle.
At each 5,000 mile segment through 75,000 miles.	B1. Perform steps A2 through A7.
At mileage specified by manufacturer	B2. Oil and filter change.
At major maintenance point.	C1. Oil and filter change. C2. Perform steps A2 through A6. C3. Perform maintenance as required by manufacturer. C4. Perform steps A2 through A7.

E.C.S. LABORATORIES INC.
12257 Market Street
Livonia Mich. 48150

Laboratory Cross Check Report

BOTTLE ANALYSIS:					BOTTLE READING:						
Bottle #	CO ppm	CO2 %	C3 ppm	C1 ppm	DATE	LAB	CO ppm	CO2 %	C3 ppm	C1 ppm
843912	50.4	0.952	151.8	50.6	07/22/88	ATL	50.00	0.950	160.2	53.40
843912	50.4	0.952	151.8	50.6	07/28/88	ECS-v	50.10	0.949	163.8	54.61
849851	50.6	0.977	149.4	49.8	08/19/88	ECS-v	49.60	0.956	159.0	53.00
849851	50.6	0.977	149.4	49.8	08/26/88	ATL	50.52	0.969	164.2	54.73

Attachment 1-9

SECTION A (Cont'd.)
SCHEDULED MAINTENANCE SERVICES

CAR GROUPS C, G, H and I

SCHEDULE II

Follow Schedule II *only* if none of the driving conditions specified in Schedule I apply.

The services shown in this schedule up to 45 000 miles (75 000 km) are to be performed after 45 000 miles at the same intervals.

ITEM NO.	TO BE SERVICED	WHEN TO PERFORM Miles (kilometers) or Months, Whichever Occurs First	MILES (000) 7.5 / KILOMETERS (000) 12.5	15 / 25	22.5 / 37.5	30 / 50	37.5 / 62.5	45 / 75
1	Engine Oil Change (Turbocharged, see †)*	Every 7 500 mi. (12 500 km) or 12 mos.	●	●	●	●	●	●
	Oil Filter Change*†	At first and then every other oil change or 12 mos.	●		●		●	
2	Chassis Lubrication	Every 7 500 mi. (12 500 km) or 12 mos.	●	●	●	●	●	●
3	Carburetor Choke & Hose Inspection (if equipped)*♦	At 7 500 mi. (12 500 km) and then at each 30 000 mi. (50 000 km) interval	●			●		
4	Carburetor or Throttle Body Mounting Bolt Torque (some models)*	At 7 500 mi. (12 500 km) only	●					
5	Engine Idle Speed Adjustment (Some Models)*		●					
6	Tire & Wheel Inspection & Rotation	At 7 500 mi. (12 500 km) and then every 15 000 mi. (25 000 km)	●		●		●	
7	Vacuum or A.I.R. Pump Drive Belt Inspection*	Every 30 000 mi. (50 000 km) or 24 mos.				●		
8	Cooling System Service*					●		
9	Front Wheel Bearing Repack (Rear-Wheel-Drive Cars Only)	See explanation on page 7.						
10	Transmission/Transaxle Service							
11	Spark Plug Service*	Every 30 000 mi. (50 000 km)				●		
12	Spark Plug Wire Inspection (some models)*♦					●		
13	PCV Valve Inspection (some models)*♦					●		
14	EGR System Inspection (some models)*♦	Every 30 000 mi. (50 000 km) or 36 mos.				●		
15	Air Cleaner & PCV Filter Replacement*					●		
16	Engine Timing Check (some models)*					●		
17	Fuel Tank, Cap & Lines Inspection*♦	Every 30 000 mi. (50 000 km)				●		
18	Thermostatically Controlled Air Cleaner Inspection* (some models)					●		

*An Emission Control Service

♦*The U.S. Environmental Protection Agency has determined that the failure to perform this maintenance item will not nullify the emission warranty or limit recall liability prior to the completion of vehicle useful life. however, urges that all recommended maintenance services be performed at the indicated intervals and the maintenance be recorded in section C.*

† *Turbocharged Engines.*

VIN engine code M—change oil every 3 000 miles (5 000 km) or 3 months, whichever comes first. Change engine oil filter at first oil change, then every other oil change.

NOTE: To determine engine code and displacement, see the Specifications Section of your Owner's Manual.

Attachment 1-10

Attachment 1-11

MAINTENANCE SCHEDULE FOR CAR GROUP D

SCHEDULED MAINTENANCE SERVICES FOR EMISSION CONTROL AND PROPER VEHICLE PERFORMANCE

Inspection and Service should be performed anytime a malfunction is observed or suspected. Retain receipts for all vehicle emission services to protect your emission warranty.

COMPONENT MAINTENANCE	SERVICE	MILEAGE IN THOUSANDS	7.5	15	22.5	30	37.5	45
EMISSION RELATED	INTERVALS	KILOMETERS IN THOUSANDS	12	24	36	48	60	72
REPLACE SPARK PLUGS		AT					X	
INSPECT AND ADJUST TENSION ON DRIVE BELTS: REPLACE AS NECESSARY		AT	X(2)					X(2)

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COMPONENT MAINTENANCE	SERVICE	MILEAGE IN THOUSANDS	7.5	15	22.5	30	37.5	45
NON-EMISSION RELATED	INTERVALS	KILOMETERS IN THOUSANDS	12	24	36	48	60	72
ENGINE OIL FILTER REPLACE AT EVERY SECOND OIL CHANGE (4)		OR		X		X		X

(1) Where time and mileage are shown, follow the interval which occurs first.
(2) For California vehicles, this maintenance is recommended by (but is not required to maintain the warranty on the air pump drive belt.
(3) If mileage is less than 7,500 miles (12 000 km) each 12 months, replace oil filter at each oil change.

Inspection and service should be performed anytime a malfunction is observed or suspected.

MAINTENANCE SERVICE FOR PROPER VEHICLE PERFORMANCE

MAINTENANCE SERVICE	SERVICE INTERVALS
COOLING SYSTEM	CHECK AND SERVICE AS REQUIRED EVERY 12 MONTHS
	DRAIN, FLUSH AND REFILL AT 36 MONTHS OR 52,500 MILES 84 000 KILOMETERS ... AND EVERY 24 MONTHS OR 30,000 MILES - 48 000 KILOMETERS THEREAFTER
BRAKE HOSES, FUEL HOSES	INSPECT FOR DETERIORATION AND LEAKS WHENEVER BRAKE SYSTEM IS SERVICED AND EVERY OIL CHANGE. REPLACE IF NECESSARY.
BRAKE LININGS - FRONT & REAR AND REAR WHEEL BEARINGS	INSPECT EVERY 22,500 MILES - 36 000 KILOMETERS
TIE ROD ENDS & BALL JOINTS	LUBRICATE EVERY 3 YEARS OR 30,000 MILES - 48 000 KILOMETERS
DRIVE SHAFT BOOTS	INSPECT FOR DETERIORATION AND LEAKS EVERY OIL CHANGE. REPLACE IF NECESSARY

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Attachment 1-12

MAINTENANCE SCHEDULE FOR CAR GROUP E

CUSTOMER MAINTENANCE SCHEDULE B

Follow Maintenance Schedule B, if, generally, you drive your vehicle on a daily basis for several miles and NONE OF THE DRIVING CONDITIONS SHOWN IN SCHEDULE A APPLY TO YOUR DRIVING HABITS.

PERFORM AT THE MONTHS OR DISTANCES SHOWN, WHICHEVER OCCURS FIRST.								
MILES (000)	7.5	15	22.5	30	37.5	45	52.5	60
KILOMETERS (000)	12	24	36	48	60	72	84	96
EMISSION CONTROL SERVICE								
Change engine oil and oil filter (every 6 months) OR 7500 miles, whichever occurs first	X	X	X	X	X	X	X	X
Replace spark plugs				X				X
Change crankcase filter (1)				X(1)				X(1)
Inspect accessory drive belt(s)				X				X
Replace air cleaner filter (1)				X(1)				X(1)
Replace engine coolant (every 36 months) OR				X				X
Check engine coolant protection, hoses and clamps	ANNUALLY							
GENERAL MAINTENANCE								
Check exhaust heat shields				X				X
Inspect disc brake pads and rotors (front) (2)				X(2)				X(2)
Inspect brake linings and drums (rear) (2)				X(2)				X(2)
Inspect and repack rear wheel bearings.				X				X

(1) If operating in severe dust, more frequent intervals may be required, consult your dealer.

(2) If your driving includes continuous stop-and-go driving or driving in mountainous areas, more frequent intervals may be required.

Attachment 1-13

MAINTENANCE SCHEDULE FOR CAR GROUP F

CUSTOMER MAINTENANCE SCHEDULE B

Follow Maintenance Schedule B if, generally, you drive your vehicle on a daily basis for several miles and **NONE OF THE DRIVING CONDITIONS SHOWN IN SCHEDULE A APPLY TO YOUR DRIVING HABITS.**

PERFORM AT THE MONTHS OR DISTANCES SHOWN, WHICHEVER OCCURS FIRST.								
MILES (000)	7.5	15	22.5	30	37.5	45	52.5	60
KILOMETERS (000)	12	24	36	48	60	72	84	96
EMISSION CONTROL SERVICE								
Change engine oil and oil filter (every 6 months) OR 7500 miles, whichever occurs first	X	X	X	X	X	X	X	X
TURBOCHARGED ENGINES — Replace spark plugs		(X)		X		(X)		X
(Four Cylinder) Change oil and filter	EVERY 5,000 MILES (8 000 km) OR 6 MONTHS, WHICHEVER OCCURS FIRST							
Replace spark plugs				X				X
Inspect accessory drive belt(s)				X				X
Replace PCV valve — 5.0L engine		(X)		(X)		(X)		(X)
Change crankcase filter (1)				X(1)				X(1)
Replace air cleaner filter (1)				X(1)				X(1)
Check/clean choke linkage (5.8L only)				X				X
Replace engine coolant (every 36 months) OR				X				X
Check engine coolant protection, hoses and clamps	ANNUALLY							
GENERAL MAINTENANCE								
Inspect exhaust heat shields				X				X
Lubricate steering and/or suspension		X		X		X		X
Lubricate steering linkage (inner-outer tie rod ends both sides, pitman arm socket) Crown Victoria/Grand Marquis		X		X		X		X
Inspect disc brake pads and rotors (front) (2)				X(2)				(X2)
Inspect brake linings and drums (rear) (2)				X(2)				X(2)
Inspect and repack front wheel bearings				X				X

(1) If operating in severe dust, more frequent intervals may be required. Consult your dealer.
(2) If your driving includes continuous stop-and-go driving or driving in mountainous/hilly areas, more frequent intervals may be required.

(X) This item not required to be performed, however, recommends that you also perform maintenance on items designated by an (X) in order to achieve best vehicle operation. Failure to perform this recommended maintenance wil not invalidate the vehicle emissions warranty or manufacturer recall liability.

Attachment 1-14

MAINTENANCE SCHEDULE FOR CAR GROUP T

CUSTOMER MAINTENANCE SCHEDULE B

Follow Maintenance Schedule B if, generally, you drive your car on a daily basis for several miles and **NONE OF THE DRIVING CONDITIONS SHOWN IN SCHEDULE A APPLY TO YOUR DRIVING HABITS.**

PERFORM AT THE MONTHS OR DISTANCES SHOWN, WHICHEVER OCCURS FIRST.								
MILES (000)	7.5	15	22.5	30	37.5	45	52.5	60
KILOMETERS (000)	12	24	36	48	60	72	84	96
EMISSION CONTROL SERVICE								
Change engine oil and oil filter (every 6 months) OR 7500 miles, whichever occurs first	X	X	X	X	X	X	X	X
Replace spark plugs 2.5L HSC 4-cylinder, 3.8L V-6				X				X
Replace spark plug — 3.0L V-6 (platinum plugs)								X
Change crankcase filter — four cylinder engines only				X(1)				X(1)
Inspect accessory drive belt(s)				X				X
Replace air cleaner filter (1)				X(1)				X(1)
Replace engine coolant (every 36 months) OR				X				X
Check engine coolant protection, hoses and clamps	ANNUALLY							
GENERAL MAINTENANCE								
Check exhaust heat shields				X				X
Inspect disc brake pads and rotors (front) (2)				X(2)				X(2)
Inspect brake linings and drums (rear) (2)				X(2)				X(2)
Inspect and repack rear wheel bearings.				X				X

(1) If operating in severe dust, more frequent intervals may be required, consult your dealer.

(2) If your driving includes continuous stop-and-go driving or driving in mountainous areas, more frequent intervals may be required.

Attachment 1-15

Maintenance Activity - Group C

Table 1

2.0L I-4 TBI

Car	Miles	Maintenance Performed	Reason
C-1	30,034	Scheduled maintenance	See Attachment 1-10
	51,260	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,035	Scheduled maintenance	See Attachment 1-10
C-2	38,328	Rebuild engine	Engine failure-spun bearings, not fuel related
	30,100	Scheduled maintenance	See Attachment 1-10
	51,201	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,046	Schedule maintenance	See Attachment 1-10
C-3	30,060	Scheduled maintenance	See Attachment 1-10
	51,229	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,045	Scheduled maintenance	See Attachment 1-10
C-4	30,036	Scheduled maintenance	See Attachment 1-10
	51,491	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,036	Scheduled maintenance	See Attachment 1-10
C-5	30,036	Scheduled maintenance	See Attachment 1-10
	51,240	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,057	Scheduled maintenance	See Attachment 1-10
C-6	30,073	Scheduled maintenance	See Attachment 1-10
	51,246	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,050	Scheduled maintenance	See Attachment 1-10

Attachment 1-15

Maintenance Activity - Group D

Table 2

3.0L V-6 MPEFI

Car	Miles	Maintenance Performed	Reason
D-1	23,457	Replace speedometer head	Mileage problems
	35,080	Scheduled maintenance	See Attachment 1-11
	50,035	Replace injectors New fuel pump	Test protocol Pump failure
	50,120	Replace air temp sensor	Stumbling on acceleration
	59,951	Scheduled maintenance	See Attachment 1-11
D-2	35,129	Scheduled maintenance	See Attachment 1-11
	50,185	Replace injectors New fuel pump	Test protocol Pump failure
	50,280	Replace air temp sensor	Stumbling on acceleration
	60,087	Scheduled maintenance	See Attachment 1-11
D-3	7,485	Car totalled; replaced with D-3A	
	23,344	Replace speedometer head	Mileage problem
	25,000	Replace injectors	Starting problems
	35,000	Scheduled maintenance	See Attachment 1-11
	50,200	Replace injectors New fuel pump	Test protocol Pump failure
	50,270	Replace air temp sensor	Stumbling on acceleration
	59,988	Scheduled maintenance	See Attachment 1-11
D-4	35,076	Scheduled maintenance	See Attachment 1-11
	40,050	Replace lash adjusters	Engine noise
D-4	40,075	Replace injectors	Severe stumbling on acceleration
	50,060	Replace injectors New fuel pump	Test protocol Pump failure

Attachment 1-15

Maintenance Activity - Group D

Table 2 (Cont'd)

3.0L V-6 MPEFI

Car	Miles	Maintenance Performed	Reason
	50,166	Replace air temp. sensor	
	60,034	Scheduled maintenance	Marginal performance
D-5	35,049	Scheduled maintenance	Marginal performance
	48,200	Replaced canister	Component check
	48,433	Reset computer memory	Component check
	49,953	Check new oxygen sensor	Component check
	49,971	Check new computer	Component check
	50,049	Replace injectors	Test protocol
	50,151	Replace MAP sensor	Stumbling on acceleration
	50,250	Check new air temp sensor	Component check
	50,305	New fuel pump	Pump failure
	50,347	Replace air temp sensor	Failed
	60,080	Scheduled maintenance	Marginal performance
D-6	35,077	Scheduled maintenance	Marginal performance
	50,021	Replace injectors New fuel pump	Test protocol Pump failure
	50,087	Replace air temp sensor	Failed
	60,069	Scheduled maintenance	Marginal performance

Attachment 1-15

Maintenance Activity - Group E

Table 3

1.9L I-4 TBI

Car	Miles	Maintenance Performed	Reason
E-1	30,035	Scheduled maintenance	See Attachment 1-12
	35,005	Replaced transmission	Trans. failure
	39,937	New MAP sensor New fuel injector	Dealer service for driveability (tip in problem, stall on road)
	50,032	Replace injector	Test protocol
	50,067	Replace MAP sensor	Component check
	60,059	Scheduled maintenance	See Attachment 1-12
E-2	30,072	Scheduled maintenance	See Attachment 1-12
	40,363	Trans. serviced	Dark fluid
	50,034	Replace injector	Test protocol
	50,127	Replace MAP sensor	Component check
	60,004	Scheduled maintenance	See Attachment 1-12
E-3	29,994	Scheduled maintenance	See Attachment 1-12
	40,355	Trans. serviced	Dark fluid
	50,046	Replaced injector	Test protocol
	50,078	Replace MAP sensor	Component check
	60,030	Scheduled maintenance	See Attachment 1-12
E-4	30,101	Scheduled maintenance	See Attachment 1-12
	40,209	Trans. serviced	Dark fluid
	50,141	Replace injector	Test protocol
	50,189	Replace MAP sensor	Component check
	60,052	Scheduled maintenance	See Attachment 1-12

Attachment 1-15

Maintenance Activity - Group E

Table 3 (Cont'd)

1.9L I-4 TBI

Car	Miles	Maintenance Performed	Reason
E-5	30,004	Scheduled maintenance	See Attachment 1-12
	40,062	Trans. serviced	Dark fluid
	49,877	Replace injector	Test protocol
	49,917	Replace MAP sensor	Component check
	60,000	Scheduled maintenance	See Attachment 1-12
E-6	29,984	Scheduled maintenance	See Attachment 1-12
	40,335	Trans. serviced	Dark fluid
	50,075	Replace injector	Test protocol
	50,122	Replace MAP sensor	Component check
	59,984	Scheduled maintenance	See Attachment 1-12

Attachment 1-15

Maintenance Activity - Group F

Table 4

5.0L V-8 EFI

Car	Miles	Maintenance Performed	Reason
F-1	30,149	Scheduled maintenance	See Attachment 1-13
	39,799	Replace Throttle Position (TP) sensor Replace air bypass valve	Vehicle stalling
	49,943	Replace injectors	Test protocol
	60,065	Scheduled maintenance	See Attachment 1-13
F-2	30,099	Scheduled maintenance	See Attachment 1-13
	50,040	Replace injectors	Test protocol
	60,053	Scheduled maintenance	See Attachment 1-13
F-3	30,364	Scheduled maintenance	See Attachment 1-13
	50,032	Replace injectors	Test protocol
	59,975	Scheduled maintenance	See Attachment 1-13
F-4	30,114	Scheduled maintenance	See Attachment 1-13
	39,772	Repair transmission	Broken output shaft
	45,015	Replace TP sensor Replace MAP sensor	Vehicle stalling
	50,126	Replace injectors	Test protocol
	59,926	Scheduled maintenance	See Attachment 1-13
F-5	25,213	Replace MAP sensor	Failed State of MI emissions test
	29,719	Scheduled maintenance	See Attachment 1-13
	49,990	Replace injectors	Test protocol
	60,043	Scheduled maintenance	See Attachment 1-13
F-6	30,108	Scheduled maintenance	See Attachment 1-13
	45,139	Replace TP sensor Replace MAP sensor	Vehicle stalling

Attachment 1-15

Maintenance Activity - Group F

Table 4 (Cont'd)

5.0L V-8 EFI

Car	Miles	Maintenance Performed	Reason
F-6	50,042	Replace injectors	Test protocol
	60,017	Scheduled maintenance	See Attachment 1-13

Attachment 1-15

Maintenance Activity - Group G

Table 5

2.5L I-4 TBI

Car	Miles	Maintenance Performed	Reason
G-1	30,031	Scheduled maintenance	See Attachment 1-10
	58,189	Replaced transmission	Trans. failure
	60,069	Scheduled maintenance	See Attachment 1-10
G-2	30,032	Scheduled maintenance	See Attachment 1-10
	60,085	Scheduled maintenance	See Attachment 1-10
G-3	30,061	Scheduled maintenance	See Attachment 1-10
	60,060	Scheduled maintenance	See Attachment 1-10
G-4	30,073	Scheduled maintenance	See Attachment 1-10
	60,033	Scheduled maintenance	See Attachment 1-10
	73,536	Replaced Electronic Control Module (ECM)	"Check Engine Light" was on
G-5	30,072	Scheduled maintenance	See Attachment 1-10
	60,042	Scheduled maintenance	See Attachment 1-10
G-6	30,072	Scheduled maintenance	See Attachment 1-10
	55,439	Dist. Module and ECM replaced	"Check Engine Light" was on
	60,064	Scheduled maintenance	See Attachment 1-10

Attachment 1-15

Maintenance Activity - Group H

Table 6

2.8L V-6 EFI

Car	Miles	Maintenance Performed	Reason
H-1	30,063	Scheduled maintenance	See Attachment 1-10
	37,826	Replaced flywheel	Flywheel cracked
	50,088	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,207	Dist. Module replaced	Car would not start
	50,363	Replace injectors	Test protocol
	59,912	Scheduled maintenance	See Attachment 1-10
H-2	30,032	Scheduled maintenance	See Attachment 1-10
	50,154	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,429	Replace injectors	Test protocol
	60,000	Scheduled maintenance	See Attachment 1-10
H-3	30,081	Scheduled maintenance	See Attachment 1-10
	50,315	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,414	Replace injectors	Test protocol
	50,524	Replaced transmission	Trans. failure
	59,770	Scheduled maintenance	See Attachment 1-10
H-4	30,060	Scheduled maintenance	See Attachment 1-10
	50,276	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,390	Replace injectors	Test protocol
	59,776	Scheduled maintenance	See Attachment 1-10
H-5	30,109	Scheduled maintenance	See Attachment 1-10
	50,093	Replace thermostat	Overheating

Attachment 1-15

Table 6 (Cont'd)

Maintenance Activity - Group H

2.8L V-6 EFI

Car	Miles	Maintenance Performed	Reason
H-5	50,222	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,485	Replaced injectors	Test protocol
	59,769	Scheduled maintenance	See Attachment 1-10
H-6	30,035	Scheduled maintenance	See Attachment 1-10
	50,241	Trans. fluid and filter changed	Fluid had dark color, bad odor
	50,489	Replace injectors	Test protocol
	50,578	New crank sensor and Dist. Module	Poor vehicle operation: Engine "missing"
	59,795	Scheduled maintenance	See Attachment 1-10

Attachment 1-15

Maintenance Activity - Group I

Table 7

3.8L V-6 EFI

Car	Miles	Maintenance Performed	Reason
I-1	30,038	Scheduled maintenance	See Attachment 1-10
	50,226	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	50,324	Replace injectors	Test protocol
	60,041	Scheduled maintenance	See Attachment 1-10
I-2	25,092	Replace idle air control solenoid	Poor vehicle operation
	30,066	Scheduled maintenance	See Attachment 1-10
	42,655	Replace Mass air flow sensor	Poor vehicle operation
	50,226	Replace injectors	Test protocol
	50,278	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,059	Scheduled maintenance	See Attachment 1-10
I-3	30,045	Scheduled maintenance	See Attachment 1-10
	50,238	Replace injectors	Test protocol
	50,559	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,035	Scheduled maintenance	See Attachment 1-10
I-4	25,067	Replace idle air control solenoid	Poor vehicle operation
	30,067	Scheduled maintenance	See Attachment 1-10
	50,116	Replace Mass air flow sensor	Poor vehicle operation
	50,332	Replace injectors	Test protocol
	50,431	Trans. fluid and filter replaced	Fluid had dark color, bad odor

Attachment 1-15

Maintenance Activity - Group I

Table 7 (Cont'd)

3.8L V-6 EFI

Car	Miles	Maintenance Performed	Reason
I-4	50,456	Replace oxygen sensor	Oxygen sensor was broken during removal for inspection
	60,075	Scheduled maintenance	See Attachment 1-10
I-5	30,041	Scheduled maintenance	See Attachment 1-10
	50,296	Replace injectors	Test protocol
	50,386	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,066	Scheduled maintenance	See Attachment 1-10
	70,801	Replaced transmission	Trans. failure
I-6	30,036	Scheduled maintenance	See Attachment 1-10
	35,813	Replaced transmission	Trans. failure
	50,240	Replace injectors	Test protocol
	50,326	Trans. fluid and filter replaced	Fluid had dark color, bad odor
	60,034	Scheduled maintenance	See Attachment 1-10

Attachment 1-15

Maintenance Activity - Group T

Table 8

3.0L V-6 EFI

Car	Miles	Maintenance Performed	Reason
T-1	24,984	Trans. serviced	Dark fluid
	29,987	Scheduled maintenance	See Attachment 1-14
	50,114	Replace injectors Replace fuel cap	Test protocol Leaking vapors
	60,125	Scheduled maintenance	See Attachment 1-14
	60,125	Clean intake-air bypass	Dealer recommendation
T-2	24,997	Trans. serviced	Dark fluid
	30,001	Scheduled maintenance	See Attachment 1-14
	50,168	Replace injectors	Test protocol
	60,088	Scheduled maintenance	See Attachment 1-14
	60,124	Clean intake-air bypass	Dealer recommendation
T-3	25,014	Trans. serviced	Dark fluid
	30,076	Scheduled maintenance	See Attachment 1-14
	50,074	Replace injectors	Test protocol
	60,066	Scheduled maintenance	See Attachment 1-14
	60,102	Clean intake-air bypass	Dealer recommendation
T-4	1,066	Replace Oxygen sensor	Failed NOx new car spec
	25,169	Trans. serviced	Dark fluid
	30,117	Scheduled maintenance	See Attachment 1-14
	50,006	Replace injectors	Test protocol
	59,997	Scheduled maintenance	See Attachment 1-14
	60,032	Clean intake-air bypass	Dealer recommendation

Attachment 1-15

Table 8 (Cont'd)

Maintenance Activity - Group T

3.0L V-6 EFI

Car	Miles	Maintenance Performed	Reason
T-5	25,012	Trans. serviced	Dark fluid
	30,012	Scheduled maintenance	See Attachment 1-14
	50,091	Replace injectors	Test protocol
	60,028	Scheduled maintenance	See Attachment 1-14
	60,065	Clean intake-air bypass	Dealer recommendation
T-6	30,040	Scheduled maintenance	See Attachment 1-14
	50,125	Replace injectors	Test protocol
	59,991	Scheduled maintenance	See Attachment 1-14
	60,028	Clean intake-air bypass	Dealer recommendation

Attachment 1-16

INVALID EMISSION TESTS

Car No.	Odometer	Comments
General	Group:	These cars all had excessive cranking times and were difficult to start.
G1	None	
G2	5034	Misfire and surging - erratic
G2	30143	Bad start
G3	35041	Bad start - surging
G4		
G5	40008	Excessive cranking - bad start
G5	45006	Excessive cranking - bad start
G5	50009	Excessive cranking - bad start
G6	45039	Excessive cranking - poor driving
G6	50009	Excessive cranking - bad start
General H Group:		No invalid tests
General I Group:		Failures occurred in air sensing controls.
I1	None	
I2	25007	Bad start - excessive cranking - idle air control malfunction.
I2	25032	Bad start - excessive cranking - idle air control malfunction.
I2	25058	Sent to dealer for repair.
I3	None	
I4	25008 25039 25067	Run with idle air control failure. Emissions were not checked after repair-omission by site manager.
I4	50123	MAF Failure - Poor driveability.
I5	None	
I6	None	
General C Group:		No problems encountered.

Car No.	Odometer	Comments
C2	30070	The wrong calibration was in the computer and data was re-entered.
General D Group:		No problems with emissions runs, however, all cars had driveability problems after approximately 15,000 miles.
General E Group:		No car problems with exception E6 noted.
E6	35025	Bad start - run aborted.
General F Group:		Initial drive-away problems encountered.
F1	45080	T.P. switch failed - run aborted.
F1	50086	Car misfiring.
F4	39826	Car stalled - cold start drive-away.
General T Group:		All runs valid - See T4 note.
T4	43, 61 1006	O_2 sensor failure from purchase of car - replaced at the 1,000-mile point.

Final Report

APPENDIX 2A: STATISTICAL ANALYSIS OF AUTOMOTIVE EXHAUST EMISSIONS IN SUPPORT OF ETHYL'S HiTEC® 3000 FUEL WAIVER APPLICATION

SYSAPP-90/037

May 4, 1990

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Executive Summary

With the enactment of the 1977 Amendments to the Clean Air Act, Congress created a new program for regulating fuels and fuel additives intended for use in light duty gas vehicles. This program, embodied in Section 211 (f)(4) of the Act, requires manufacturers of new fuels and fuel additives to demonstrate that their products will not cause or contribute to the failure of emission control systems to meet applicable emission standards. Toward that end, Ethyl Corporation ("Ethyl") has conducted the most extensive and rigorous evaluation of a fuel additive ever undertaken by an individual company to demonstrate that the use of HiTEC® 3000 Performance Additive ("HiTEC 3000" is also known by the chemical name methylcyclopentadienyl manganese tricarbonyl or MMT) meets the requirements established in the Clean Air Act for its use in unleaded gasoline.

The test program developed by Ethyl was conducted in close consultation with the EPA and the major U.S. automobile manufacturers. This program involved the testing of 48 vehicles representing 53 percent of actual 1988 U.S. sales, each operated for 75,000 miles, under procedures described in the Code of Federal Regulations, Section 86. The resultant data (approximately 1700 emissions tests) allowed for a comprehensive study of all possible adverse effects on emission control systems that could arise from the general use of HiTEC 3000.

Systems Applications, Inc. (SAI) was retained by Ethyl Petroleum Additives, Inc. to provide statistical analysis of the emissions data generated in the test program. The statistical tests applied by SAI were based on precedents and protocols established by the EPA in previous waiver applications. In addition, the availability of a larger data base from a well-designed emissions testing program with accumulated mileage over a wider range than ever previously evaluated by the EPA in a waiver application allowed for modifications and extensions to the statistical tests developed by the

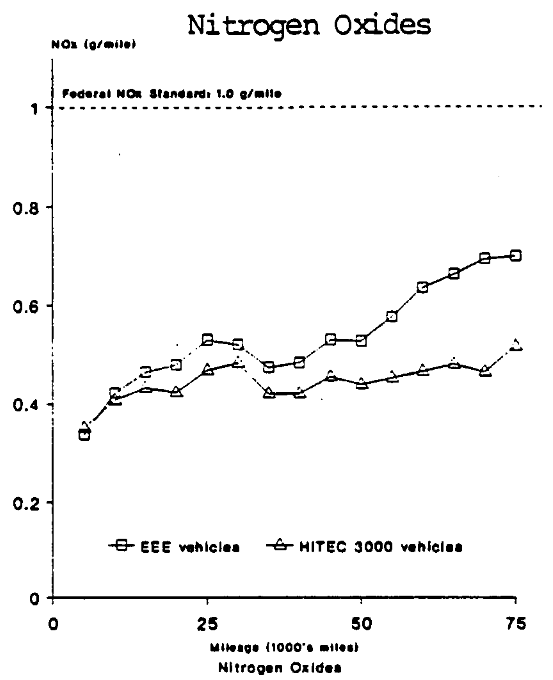
EPA. These additional, more powerful tests are important because of their ability to distinguish statistically significant effects from the use of HiTEC 3000 in unleaded gasoline.

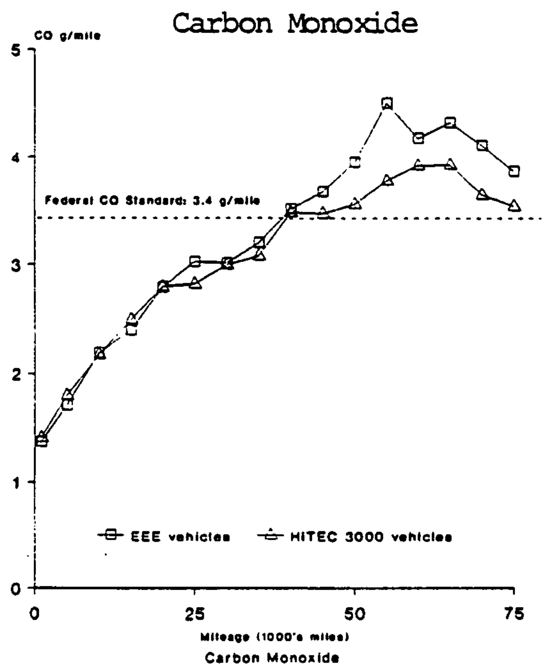
The statistical analyses reported here may be broadly defined in three types of tests. The first type of test, the initial emissions test, was developed by the EPA because of concerns that "different initial emission levels of vehicles operated on different fuels could mask a fuel effect." This test only indicates if the initial emission levels differ between the vehicles assigned to the clear-fuel and those assigned to the HiTEC 3000 fuel. In this waiver application, the "initial" emissions are at 1,000 miles, since the fuel additive was first introduced at that point; prior to 1,000 miles, all vehicles had accumulated mileage on clear fuel alone.

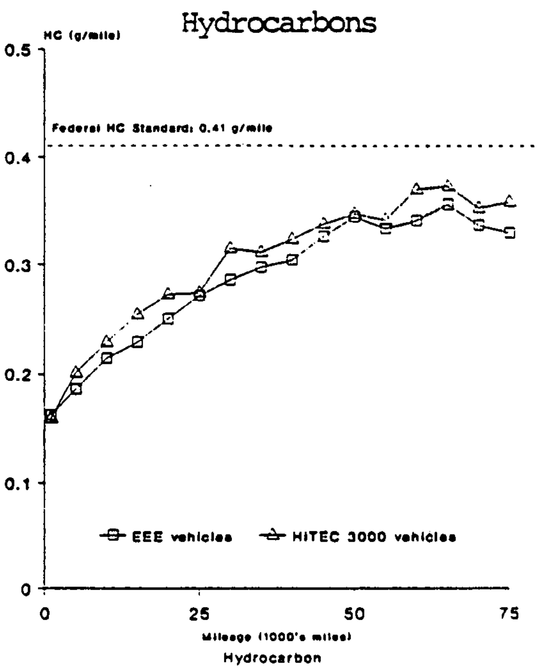
The second type of test used by the EPA for evaluating waiver applications allows an applicant to show that the fuel or fuel additive does not have a statistically significant adverse emissions effect. In an earlier HiTEC 3000 waiver application, the EPA staff applied seven statistical tests to determine the adverse effects on emissions. Four of these tests developed by the EPA and modified by SAI are based on fitting a regression model to the data, while the remaining three tests are based on an analysis of the raw data.

The third type of test established by the EPA addresses the effects of the additive on emission control systems from a different perspective. If after conducting the seven adverse-effects tests a fuel additive demonstrates a statistically significant adverse emissions effect, the EPA has applied a final test to evaluate the impact of this effect on compliance with applicable emission standards. This pivotal test evaluates whether the adverse emissions effect "causes or contributes" to a failure of a vehicle to meet the emission standards for which it was certified.

A review of the plotted 75,000 mile data for nitrogen oxide (NO_x), carbon monoxide (CO), and hydrocarbon (HC) emissions is helpful in gaining an overview of the effects of HiTEC 3000 in unleaded gasoline. The emission rates in these plots were calculated by taking the average emissions for each fuel for each vehicle group and weighting them based on 1988 sales figures.


Nitrogen Oxides
NOx (g/mile)
Federal NOx Standard: 1.0 g/mile
1
0.8
0.6
0.4
0.2
0
EEE vehicles
HITEC 3000 vehicles
0
25
50
75
Mileage (1000's miles)
Nitrogen Oxides


Carbon Monoxide
CO g/mile
Federal CO Standard: 3.4 g/mile
5
4
3
2
1
0
EEE vehicles
HITEC 3000 vehicles
0
25
50
75
Mileage (1000's miles)
Carbon Monoxide


Hydrocarbons
HC (g/mile)
Federal HC Standard: 0.41 g/mile
0.5
0.4
0.3
0.2
0.1
0
EEE vehicles
HITEC 3000 vehicles
0
25
50
75
Mileage (1000's miles)
Hydrocarbon

In viewing the results of the mileage accumulation program in this straightforward visual manner, a number of important observations can be made. The most striking and pronounced observation is the effect of HiTEC 3000 on NO_x emissions. Very shortly after the initial addition of the additive, NO_x emissions decrease and continue to decrease for the remainder of the test program. Furthermore, this beneficial effect is almost universal throughout the waiver fleet. As emission control strategies take into greater account the effects of NO_x on air quality, the improvement demonstrated by HiTEC 3000 must be considered. In the case of CO, those vehicles fueled with HiTEC 3000 show an improvement in CO emissions as compared to the clear-fueled vehicles beginning at 40,000 miles. This improvement also continues for the remainder of the mileage accumulation program. For hydrocarbons, the weighted average data clearly show that both the clear-fueled and HiTEC 3000-fueled vehicle groups meet current 50,000 mile emission standards and are still below the standard at 75,000 miles.

In the program discussed in this appendix, over 100 different statistical tests were run to evaluate the effects of HiTEC 3000 on HC, CO, and NO_x emissions. The results of the prescribed EPA tests convincingly demonstrate that the use of HiTEC 3000 in unleaded gasoline will not cause or contribute to the failure of emission control systems to meet emission standards for which they were designed. Additional statistical tests support this conclusion.

The results of this extensive analysis of 75,000 miles of accumulated mileage on 24 cars fueled with Howell EEE and 24 cars fueled with Howell EEE with HiTEC 3000 added are as follows:

- There is no significant adverse effect of HiTEC 3000 on deterioration rates before or after 50,000 miles for HC, CO, or NO_x.

- There is no significant adverse effect of HiTEC 3000 on deterioration factors for HC, CO, or NO_x.

- There is no significant adverse effect of HiTEC 3000 on the estimated mileage at which the standard is first exceeded for HC, CO, or NO_x.

- There is no significant adverse effect of HiTEC 3000 on the estimated maximum percentage of vehicles failing the standard over 50,000 miles or over 75,000 miles for HC, CO, or NO_x.

- There is no significant adverse effect of HiTEC 3000 on the increase in emissions from initial mileage (1,000 miles) to 50,000 miles for HC, CO, or NO_x.

- There is no significant adverse effect of HiTEC 3000 on the increase in emissions from initial mileage (1,000 miles) to 75,000 miles for CO or NO_x; there is a small but statistically significant effect for HiTEC 3000-fueled vehicles for HC. However this adverse effect is attributed to changes in emission system components at 50,000 miles and not HiTEC 3000.

- The change in emissions from initial mileage (1,000 miles) to 5,000 miles is not significantly greater for HiTEC 3000-fueled vehicles for CO or NO_x; there is a small but statistically significant effect for HiTEC 3000-fueled vehicles for HC.

- The integrated emissions above initial levels from initial mileage (1,000 miles) to 50,000 miles is not significantly higher for HiTEC 3000-fueled vehicles for CO or NO_x; there is a small but statistically significant increase for HiTEC 3000-fueled vehicles for HC. However, the integrated emissions above 5,000-mile levels from 5,000 to 50,000 miles is not significantly higher for HiTEC 3000-fueled vehicles for HC.

- The integrated emissions above initial levels from initial mileage (1,000 miles) to 75,000 is not significantly higher for HiTEC 3000-fueled vehicles for CO or NO_x; there is a small but statistically significant increase for HiTEC 3000-fueled vehicles for HC. However, the integrated emissions above 5,000 mile levels from 5,000 to 75,000 miles is not significantly higher for HiTEC 3000-fueled vehicles for HC.

- No adverse effects were detected in HiTEC 3000-fueled vehicles for either CO or NO_x in any of the statistical tests applied. In fact, CO and NO_x emissions are substantially lower in vehicles fueled with HiTEC 3000. The statistical results reported in this study imply that the use of HiTEC 3000 would result in statistically significant reductions in NO_x and CO emissions.

- The single adverse effect for HC, a small increase in emissions from 1,000 to 5,000 miles, does not cause or contribute to the failure of emission control systems to meet the standards for which they were designed.

The above summary shows that HiTEC 3000 passes all adverse-effects tests for all regulated pollutants, except that a small but statistically significant increase in HC in the first 4,000 miles accumulated in vehicles fueled with HiTEC 3000 is shown. The modified integrated emissions test with 5,000 miles as the base, which is passed for HC, clearly shows that the only adverse effect caused by the use of HiTEC 3000 in unleaded gasoline occurred within the first 4000 miles of operation. Despite this small HC effect, the use of this product will have no significant contributory impact on the ability of emission control systems to meet applicable standards. This is a very important result and one that must be taken into consideration in the final determination of this product's effect.

In short, HiTEC 3000 in unleaded gasoline has no statistically significant adverse effect on emissions of CO or NO_x. Long-term benefits in controlling tailpipe emissions of CO and NO_x can clearly be gained from the use of this product. While this analysis shows that HiTEC 3000 has a very small adverse effect on HC emissions between 1,000 and 5,000 miles, no additional adverse effect on HC emissions is demonstrated throughout 75,000 accumulated miles. Finally, the results generated in this large-scale, well-designed, and closely controlled program on vehicles representing 53 percent of U.S. sales show that the general use of HiTEC 3000 will not cause or contribute to the failure of emission control systems to meet applicable emission standards.

Contents

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Attachments

1 INTRODUCTION

In 1977 Congress enacted amendments to the Clean Air Act establishing a new program for the registration and testing of fuels and fuel additives to ensure that the use of such products will not cause or contribute to the failure of automobile emission control systems. In particular, section 211(f)(4) of the Act requires that the manufacturer demonstrate to the EPA that the "general use" of such products "will not cause or contribute to a failure of any emission control device or system," during its useful life, to meet the emission standards for which the vehicle has been certified under the Clean Air Act.[1] Toward that end, Ethyl Corporation ("Ethyl") has conducted a comprehensive test program to demonstrate that the use of HiTEC® 3000 Performance Additive (also known by the chemical name methylcyclopentadienyl manganese tricarbonyl or MMT) meets the requirements established in the Clean Air Act for its use in unleaded gasoline at a concentration of 0.03125 grams Mn per gallon as HiTEC 3000.

The type of test program that a manufacturer is required to conduct to support the waiver application depends on the effect that an additive is expected to have on emission control systems. In 45 Fed. Reg. 58954 (September 5, 1980), the EPA indicated that "the tests which are appropriate to characterize the emission effects of an additive depend on whether the additive is expected to have an instantaneous effect or a long-term deteriorative effect on emissions, or both." Since the enactment of the 1977 amendments to the Clean Air Act, 19 waiver applications

[1] The federal emission standards used in this analysis are 0.41 g/mile of hydrocarbon, 3.4 g/mile of carbon monoxide, and 1.0 g/mile of nitrogen oxides.

have been submitted to the EPA for approval.[2] Included in these prior applications are two waiver requests for HiTEC 3000, one of which was submitted in 1978 and another in 1981. In both of these applications the EPA concluded that Ethyl had not met the burden of proof established under Section 211(f)(4); that is, that Ethyl had not shown that the use of HiTEC 3000 would not cause or contribute to the failure of any emission control device or system to meet applicable emission standards. In both cases, however, the EPA invited Ethyl to resubmit a new waiver application whenever additional information supported such an effort.

Of the 19 waiver applications submitted to the EPA under Section 211(f)(4), only HiTEC 3000 (or MMT) has been supported by emissions data accumulated over 50,000 miles.[3] The data generated by Ethyl in support of this more recent waiver application is the most extensive and rigorous evaluation of a fuel additive ever undertaken by an individual company. It involves the testing of 48 vehicles, each operated for 75,000 miles, under procedures described in Section 86 of the Code of Federal Regulations. For comparison, the approved Texaco waiver application (43 Fed. Reg. 58954) relied upon data from only 15 vehicles.

In early 1989 Systems Applications, Inc. (SAI) was retained by Ethyl Petroleum Additives, Inc. (EPAI) to provide statistical analyses of the emissions data from the

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2 53 Fed. Reg. 33846 (September 1, 1988); 53 Fed. Reg. 3636 (February 8, 1988); 53 Fed. Reg. 2088 (January 26, 1988); 51 Fed. Reg. 28757 (August 11, 1986); 50 Fed. Reg. 2615 (January 17, 1985); 48 Fed. Reg. 52634 (November 21, 1983); 48 Fed. Reg. 8124 (February 25, 1983); 47 Fed. Reg. 22404 (May 24, 1982); 46 Fed. Reg. 58630 (December 1, 1981); 46 Fed. Reg. 56361 (November 16, 1981); 45 Fed. Reg. 58954 (September 5, 1980); 45 Fed. Reg. 53861 (August 13, 1980); 45 Fed. Reg. 26122 (April 17, 1980); 44 Fed. Reg. 37074 (June 25, 1979); 44 Fed. Reg. 12242 (March 6, 1979); 44 Fed. Reg. 20777 (April 6, 1979); 44 Fed. Reg. 10530 (February 21, 1979); 44 Fed. Reg. 1447 (January 5, 1979); 43 Fed. Reg. 41424 (September 18, 1978).

3 "Characterization Report: Analysis of MMT Fleet Data to Characterize the Impact of MMT on Tailpipe Emissions", EPA Mobile Source Enforcement Division, 1978.

test program. SAI was also retained to estimate the effects of HiTEC 3000 use on ambient air quality through the use of SAI's Urban Airshed Model. SAI applied statistical tests developed by the EPA to the data from the test program to determine the effects of HiTEC 3000 on emission control systems. In addition, because of the large body of emissions data from the test program, other statistical methods, more advanced than those used in other waiver applications, were used to examine in greater detail the probability that HiTEC 3000 does not cause or contribute to the failure of emission control systems or devices to achieve compliance with applicable automotive emission standards. Finally, the results of SAI's linear regression analysis were incorporated into MOBILE4, the EPA's computer model for generating motor vehicle emissions factors for use in its air quality studies. A complete description of results of applying the Urban Airshed Model and the emission inputs for the model are included in Appendix 5.

The next section of this appendix describes the testing program and the data sets analyzed. The third section discusses the statistical methods applied to the data. This discussion includes a review of the nine statistical tests applied by the EPA in the 1978 waiver application for HiTEC 3000 and the modifications and extensions of these tests developed by SAI (complete technical details of the statistical methods are provided in Attachment C). In the fourth section, the results obtained from the analysis of composite emissions are detailed. The results for each statistical test are shown and interpreted. The fifth and final section summarizes the results of the statistical analyses. All raw data and plots of the testing data as well as complete results of the 50,000 and 75,000 mile statistical analyses are included in attachments to this appendix. Additional attachments describe specific technical aspects of the statistical analyses.

2 TESTING PROGRAM DATA BASE

DESCRIPTION OF ETHYL'S TEST PROGRAM

In developing the programs required to determine if the use of HiTEC 3000 causes or contributes to the failure of emission control systems or devices, Ethyl designed the test protocols in close consultation with the EPA and the major automotive manufacturers. Because of concerns raised by the EPA in regards to the representativeness of the test fleet developed by Ethyl to support its 1978 waiver application for HiTEC 3000, special care was taken in selecting the 1988 vehicle models for the mileage accumulation phase of the test program supporting this waiver application. The eight models selected for testing were chosen based on estimated 1988 U.S. sales figures. These selected models represent the most popular engine configurations for that year and included all major U.S. automobile manufacturers. (A more complete description of the vehicle selection process is available in Appendix 1.) The model groups and the percent of U.S. sales each group represents are listed in the table below. The model group codes shown in the table appear in the tabulated results of the statistical analysis. The normalized weighted percent of sales for each model group was used for the statistical analysis. It should be noted that while projected 1988 sales figures were used to select representative model groups, actual 1988 sales figures were available and were used for the statistical analysis of the test data.

Model Group (by code)[a]	Engine Configuration[b]		Percent of Actual 1988 U.S. Sales	Normalized Weighted Percent
C	2.0L, L-4	EFI	5.7	10.6
D	3.0L, V-6	MFI	1.9	3.6
E	1.9L, L-4	EFI	5.5	10.4
F	5.0L, V-8	SFI	7.2	13.4
G	2.5L, L-4	EFI	4.2	7.9
H	2.8L, V-6	MFI	12.9	24.3
I	3.8L, V-6	SFI	9.3	17.4
T	3.0L, V-6	MFI	6.6	12.4
			53.3	100.0

[a] These codes appear in the tabulated results of the statistical analyses.

[b] EFI = Electronic fuel injection, MFI = Multi-port fuel injection, SFI = Sequential fuel injection.

To demonstrate that the use of HiTEC 3000 in unleaded gasoline has no long-term deteriorative effect on any emission control system or device, 24 vehicles of Ethyl's test fleet (three vehicles in eight model groups) were to accumulate 75,000 miles using Howell EEE certification gasoline; the remaining 24 vehicles were to accumulate the same mileage with Howell EEE plus 0.03125 grams Mn/gallon as HiTEC 3000. All mileage was to be accumulated using an EPA-approved mileage accumulation procedure for testing emission system durability. Emission tests for hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) were to be conducted at 0 miles (receipt of vehicles at test laboratory), 1,000 miles, 5,000 miles, and at each 5,000 mile interval thereafter. Based on discussions with the EPA during the initial phases of the program, the Federal Test Procedure (FTP) for exhaust emissions testing, as described in 40 CFR Part 86, was the test method used at each test point. (See Appendix 1 for details on the testing protocol and fuel specifications.)

Because of the size of Ethyl's test fleet (48 vehicles), two vehicle test sites were used. The two test laboratories chosen were ECS Laboratory, Inc. in Livonia, Michigan, and Automotive Testing Laboratories, Inc. (ATL) in South Bend, Indiana. The mileage accumulation procedure at ECS Laboratories employed a 60 mile loop on public roads. At ECS, emissions testing for most of the intervals before 50,000 miles was conducted by a single tester, who became ill during the program and was replaced by several testers for the balance of the required tests.[4] At ATL, mileage was accumulated at the Bendix Automotive Proving Ground track; emissions testing was assigned on a more or less random basis to over 25 testers throughout the mileage accumulation phase.

All vehicles were obtained from dealerships in the Detroit area and shipped to ECS Laboratories for initial screening and preparation. By protocol, for the first 1,000 miles of accumulation, all 48 vehicles were fueled with Howell EEE certification gasoline for engine break-in. At 1,000 miles duplicate tailpipe emissions tests were conducted on each vehicle and ranked, in descending order, according to average hydrocarbon emissions per vehicle. Once this ranking was completed, the highest emitting vehicle in each model group was assigned one of the fuel types by random coin toss. The second-highest ranked vehicle was assigned the other fuel type. The vehicle ranked third in hydrocarbon emissions was assigned the fuel corresponding to vehicle 2, while the fourth vehicle was assigned the fuel corresponding to vehicle 1. Vehicles ranked 5 and 6 were given the fuel assignments of vehicles 1 and 2, respectively.

Upon completion of the ranking and fuel assignment process, the 24 vehicles in model groups C, G, H, and I were transported to ATL Laboratories for all further mileage accumulation. The remaining 24 vehicles in model groups D, E, F, and T remained at ECS Laboratories.

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[4] For this program a "tester" is defined as that individual who drives a test vehicle during the FTP emissions test. A "driver" is that individual who drives a vehicle for mileage accumulation.

General Procedures Followed During Mileage Accumulation and Emissions Testing

At each test interval three bag samples were collected: one for cold start, one for running (hot stabilized) emissions, and one at hot start. The samples were analyzed and a composite emissions profile (in grams per mile) was calculated as a weighted average of the three samples using standard FTP weighting factors per bag. The collection and analysis of the three bag samples under the prescribed conditions was repeated at least once. If the composite emissions profile varied widely for any of the three pollutants (HC, CO, NO_x), an additional test was run. Test engineers determined subjectively what constituted a "wide difference". A hydrocarbon difference of 0.05 g/mi was usually sufficient reason for an additional test.

In a few instances a mechanical or procedural problem occurred during the running of an emissions test. In these instances the test was considered invalid and the observation in the raw data set (Lotus 123 spreadsheets) was marked. This identified the test as a "justifiable drop" from an engineering standpoint. A complete explanation and summary of these invalid tests is contained in Appendix 1.

Procedures for vehicle maintenance were also established during the mileage accumulation and emissions testing phase. Because of the importance proper maintenance plays in emissions control, all 48 vehicles in the test fleet were carefully maintained. During the mileage accumulation testing, both scheduled and unscheduled maintenance was performed as required. Scheduled maintenance activities were defined as the maintenance recommended by the automobile manufacturer at specified mileage accumulation points. Unscheduled maintenance was performed only as necessary to maintain proper vehicle operations, following CFR procedures for certification. A complete listing of scheduled and unscheduled maintenance activities is provided in Appendix 1.

Although the fleet vehicles were originally scheduled to accumulate only 50,000 miles of emissions data, the total mileage was increased to 75,000 because of potential changes to the Clean Air Act resulting from proposed amendments currently under debate in Congress. At 50,000 miles the emission control systems for all vehicles in the fleet were carefully inspected, and emission system components were replaced in most vehicles. These inspections and component changes were done to determine what, if any, effect on tailpipe emissions was the result of component malfunctions after 50,000 accumulated miles. By design, an attempt was made to be as consistent as possible in the treatment of each vehicle within a model group. If a component of one vehicle was changed, the same component in all other vehicles within that model group was also changed. The component changes made at 50,000 miles are listed in Table 2-1. As noted, no component changes were made at this mileage point for model groups C and G.

Two additional points in regards to the waiver fleet activities should be discussed. First, as part of Ethyl's program to examine whether the use of HiTEC 3000 adversely affects ambient air quality, two vehicles from model group F were removed from the fleet after accumulating just over 65,000 miles and shipped to Southwest Research Institute for analysis of the hydrocarbon composition of the collected emissions (described in Appendix 4). Thus the final emission measurements of these two vehicles in the data sets are at 65,000 miles. Second, vehicle D3 from model group D was involved in a traffic accident at 7,485 miles and destroyed. Because the accident occurred early in the test program, another vehicle (with 15,554 accumulated miles) was obtained and designated D3A. The emissions control system of D3 was removed and placed on D3A and this new vehicle was substituted into the mileage accumulation program; thus the mileage recorded in the data file is for the emissions control system of D3 and the engine of D3A. Because of the potential confusion created by the use of the emission control system of D3 on this new vehicle, as well as questions that could arise concerning the integrity of this arrangement, all emission tests from D3A are excluded from the main data set used in the statistical analysis.

TABLE 2-1. Component changes at 50,000 miles.*

Model	Component Changes
C	None
D	Fuel injectors Fuel pump Air sensor
E	Fuel injectors Map sensor
F	Fuel injectors Temporary slave canister (vehicle F3 only)
G	None
H	Transmission service, fuel injectors Ignition service (vehicle H1 only)
I	Fuel injectors
T	Fuel injectors

* Unless otherwise noted, component changes were made to all six vehicles in each model group.

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DATA SET GENERATION

Special attention was given to the creation of the data sets for analysis. This step is important because it defines the information used in the statistical tests and its presentation in the waiver.

In 43 Federal Register 11258 (March 17, 1978) the EPA published a series of guidelines that apply to waiver applications for fuel additives under Section 211(f) of the Clean Air Act. In these guidelines the EPA states that "it is essential that test data provide a reliable basis for comparison with the conditions under which vehicles are certified pursuant to Section 206 of the Clean Air Act." Throughout this waiver program it has been generally assumed by Ethyl that the regulations that apply to the certification of new automobile models under the Clean Air Act would also apply to test programs for fuel waivers. For that reason, decisions on what data to include in the working data sets for analysis for this waiver application were based on the sections of the Code of Federal Regulations that pertain to certification and test procedures for exhaust emissions (40 CFR Part 86 as of January 31, 1990).

Because of the importance placed on those specific sections of the Code of Federal Regulations, we shall discuss several of the specific paragraphs that are relevant to this waiver application.

> **86.088-28(a)(4)(A)** "The applicable results to be used unless excluded by paragraph (a)(4)(i)(A)(4) of this section in determining the exhaust emission deterioration factors for each engine-system combination shall be:
>
> 1. All valid exhaust emission data from the tests required under 86.084-26(a)(4) except the zero-mile tests.
>
> 2. All exhaust emission data from the tests conducted before and after the scheduled maintenance provided in 86.088-25.
>
> 3. All exhaust emission data from tests required by maintenance approved under 86.088-25, in those cases where the Administrator conditioned his approval for the performance of such maintenance on the inclusion of such data in the deterioration factor calculation.

4. The manufacturer has the option of applying an outlier test procedure to completed durability data.... The outlier procedure will be specified by the Administrator. For any pollutant, durability-data test points that are identified as outliers shall not be included in the determination of deterioration factors if the manufacturer has elected this option."

Comments: These paragraphs imply that all emissions test results except those associated with the zero-mile point and those conducted before unscheduled maintenance be used in the statistical analysis. This would include all results obtained before and after scheduled maintenance and after unscheduled maintenance. Examination of the data in the initial stages of analysis revealed no outliers, and so no tests were deleted as a result of an outlier test procedure.

86.084-26(a)(6)(i)(A) "The manufacturer may conduct multiple tests at any test point at which the data are intended to be used in the deterioration factor. At each test point where multiple tests are conducted, the test results from all valid tests shall be averaged to determine the data point to be used in the deterioration factor calculation except under paragraph (a)(6)(i)(B) of this section. The test results from emission tests performed before maintenance affecting emissions shall not be averaged with test results after the maintenance".

86.084-26(a)(6)(i)(B) "The manufacturer is not required to average multiple tests if the manufacturer conducts no more than three tests at each test point and if the number of tests at each test point is equal. All test points must be treated the same for all exhaust pollutants".

86.088-28(a)(4)(i)(B) "All applicable exhaust emission results shall be plotted as a function of the mileage on the system, rounded to the nearest mile, and the best fit straight lines, fitted by the method of least squares, shall be drawn through all these data points".

Comments: The implication of the first two paragraphs is that the means for each car at each testing interval should be weighed equally. This assumes that the mean emissions for each individual vehicle is the same as that for all vehicles in the same model group on the same fuel. Therefore careful consideration must be given to those instances where there are a different number of tests per car per testing interval. When the design is balanced (i.e., the same number of tests for each vehicle at each testing interval), the same regression line will be predicted whether one uses all the data or just the averages (although confidence intervals will be different). However, in a design that is unbalanced the predicted regression line using all data will differ from that predicted from one using average data.

DESCRIPTION OF DATA SETS

The data sets used in the statistical analyses to examine whether HiTEC 3000 causes or contributes to the failure of emission control systems were generated from raw data supplied to SAI (as Lotus 123 spreadsheets) by the mileage accumulation test laboratories. The data sets were constructed sequentially, each data set being a subset of the previous data set. The data sets created and the emissions tests excluded at each step are as follows:

ETHYL0S Data set as received from the mileage accumulation test laboratory. No records are excluded, except one test for the replacement vehicle designated D3A: the single test of D3A at 15,554 miles (initial mileage upon receipt). All tests of the replacement car with the old car's emissions control system (labeled as D3A) are included.

ETHYL1S All zero-mile tests are excluded, as per 40 CFR 86.088-28(a)(4)(i)(A)(1).

ETHYL2S All tests that are invalid from an engineering point of view and therefore considered to be "justifiable drops" are excluded. These include the 1,000 mile tests conducted at Automotive Testing Laboratories whose exclusion is justifiable on both statistical and engineering grounds (See Appendix 1 and Attachment F). Also dropped in this data set are all measurements from vehicle D3A.

ETHYL3S Tests preceding unscheduled maintenance tests are excluded per 40 CFR 86.088-28.

ETHYL4S Extra tests beyond the standard two tests are excluded. If these tests were included, the variance calculations for the statistical tests would be biased. These are the tests that were performed because the results from the first two tests were considered to be too discrepant. In the majority of instances the mileage intervals have only two tests per vehicle. In data set ETHYL3S, for example, only about 25 percent of the testing intervals have extra tests. There are three types of exceptions to this use of only two tests at each mileage interval. First, at scheduled maintenance (35,000 miles and 60,000 miles for model group D; 30,000 miles and 60,000 miles for all other model groups), emissions were tested before and after maintenance; thus for these intervals there are typically four tests (two before and two after maintenance). Second, tests performed after unscheduled maintenance are considered separately from tests at the required mileage intervals. For example, vehicle H1 has four tests at the 40,000 mile interval — two for the unscheduled maintenance at 37,826 miles and two for the regular 40,000 mile tests. Third, tests were performed before and after 50,000 mile component changes. At this mileage point there are typically four tests (two before and two after component changes).

On October 12, 1989 a meeting was held in Washington, D.C. with representatives from the EPA's Office of Mobile Sources to review the statistical analysis work that had been completed to date. At that meeting a presentation was made and discussion held on the relevant sections of the Code of Federal Regulations, the data sets generated, and the justification for dropping data points based on the interpretation of the CFR. Following this review, the EPA indicated that the approach taken seemed "reasonable".

ADDITIONAL DATA SETS FOR 75,000 MILE ACCUMULATION

As mentioned above, the original design of the HiTEC 3000 testing program called for only 50,000 accumulated miles and emissions testing in accordance with current requirements under Section 211(f) of the Clean Air Act. The scope of the testing program was increased to include 75,000 miles of vehicle operation in light of the ongoing debate concerning reauthorization of the Act.

Because of the change in mileage accumulation, certain aspects of the testing program that had been completed needed to be reviewed to insure that the data past

50,000 miles would be internally consistent with data up to and including 50,000 miles. The aspect that most obviously demanded evaluation was the component changes that had occurred at 50,000 miles. As discussed earlier, these changes were made to determine what effects on tailpipe emissions were the result of the deterioration of components up to 50,000 miles. An analysis of the data following the 50,000 mile component changes indicated that, in general, statistically significant increases in emissions from vehicles occur about as frequently as statistically significant decreases in emissions; however some changes were substantially larger than others (see Attachment G). For example, in model group D a very large and statistically significant decrease in CO emissions occurred with both fuel types. Further, the vehicles in this model group fueled with HiTEC 3000 also exhibited a statistically significant decrease in HC emissions after component changes. In addition, in model groups G and H, increases in HC and CO emissions from vehicles using HiTEC 3000 were found to be statistically significant, while increased emissions from vehicles using the clear fuel (Howell EEE) were nonsignificant. These changes can be seen in the data plots in Attachment B.

The change in mileage accumulation scope also required reevaluation of tester bias. As discussed previously, most of the pre-50,000 mile tests at ECS were performed by one individual. Tests after 50,000 miles were conducted by other ECS testers while the original tester was on sick leave. This change raised the question of whether emission test results were affected in any way by the use of several testers. If a tester bias did exist, it would be more difficult to estimate how much of the variance between results was associated with the fuel type as opposed to the tester. Again, an analysis was conducted to determine if tester choice had statistically significant effects on test results. For example, a statistical test was performed on model group D for HC. The results from this test, as well as those for other model groups, are reported in Attachment H and indicate that statistically significant differences from the original tester are evident in many model groups and for all three pollutants.

In order to properly and consistently analyze all of the data from the mileage accumulation program to 75,000 miles, three new data sets were created from data set ETHYL4S. These data sets, which are adjusted for component change and tester effects, are as follows:

ETHYL4S2 The two emissions tests performed after the component changes at 50,000 miles are deleted for all vehicles in the program. The tests performed before component changes are retained.

ETHYL4S3 Adjustments for component changes are calculated from the statistical analysis discussed in Attachment G (the effect for each pollutant/fuel/model combination is calculated separately as the mean effect across vehicles) for all measurements past 50,000 miles.

ETHYL4S4 Adjustments for tester effects at ECS Laboratories are added to all measurements after 50,000 miles in data set ETHYL4S2. Details of the analysis are provided as Attachment H.

The main data set for assessing the effects of HiTEC 3000 is ETHYL4S2; a complete listing of this data set is provided as Attachment A. Some analysis was repeated on ETHYL4S, ETHYL4S3, and ETHYL4S4, with little change in results or interpretation. The results are described in detail in Section 4.

The numbers of emissions tests read, kept, and dropped in each data set are shown below:

Data Set	Read	Kept	Dropped
ETHYL0S	2605	2604	1
ETHYL1S	2604	2440	164
ETHYL2S	2440	2304	136
ETHYL3S	2304	1965	339
ETHYL4S	1965	1814	151
ETHYL4S2	1814	1712	102

3 STATISTICAL METHODS

The statistical tests that the EPA has used to determine whether a fuel additive causes or contributes to the failure of vehicles to meet applicable emission standards are described in 43 Fed. Reg 41424 (long-term deteriorative effect) and 45 Fed. Reg. 58954 (instantaneous effect). Details on the long-term tests also appear in "Characterization Report: Analysis of MMT Fleet Data to Characterize the Impact of MMT on Tailpipe Emissions" (EPA Mobile Source Enforcement Division, 1978), hereinafter referred to as the "Characterization Report." To detect long-term deteriorative effects, the EPA has applied seven adverse-effects tests and a cause-or-contribute test (see Characterization Report).

These tests, described in 43 Fed. Reg. 41424 and the Characterization Report, have been used by EPA to determine whether a fuel or fuel additive causes or contributes to the failure of emission control devices or systems to meet applicable emission standards over time.

The seven adverse-effects tests established by the EPA allow an applicant to show that the fuel or fuel additive "does not have a statistically adverse emissions effect". In the 1978 HiTEC 3000 waiver decision (43 Fed. Reg. 41424), the EPA staff applied these seven statistical tests to evaluate the additive's effects on emissions. Four of these tests are based on fitting a simple linear regression model, while three are based on the data without fitting any regression model. These statistical tests and the initial emissions test are as follows (a more detailed description of each test is given in Attachment C):

(1) Initial emissions test. The "Characterization Report" expressed concern that "different initial emission levels of vehicles operated on different fuels could mask a fuel effect." A sign test and Mann-Whitney test were

performed to determine if the average initial emissions are the same whether or not an additive is used. In this waiver application the "initial" emissions are at 1,000 miles, since the fuel additive was first added at that point. We note that the initial emissions test only indicates if the initial emission levels differ between the cars assigned to the EEE group and those assigned to the HiTEC 3000 group. No adverse effect can be detected at the initial mileage interval since all cars had accumulated the initial mileage on only Howell EEE fuel without the HiTEC 3000 additive.

(2) 1K to 5K test. This test was developed to determine if an additive with an expected long-term effect causes an increase in emissions during initial mileage accumulation. For each combination of vehicle group and fuel, the change in average emissions from 1,000 to 5,000 miles is computed. A sign test is performed by determining if the number of vehicle groups for which the change is greater using the additive is statistically significant. A Mann-Whitney test is also performed using the observed changes for each vehicle; this test determines whether, on average, the change in emissions for vehicles using the additive is higher than for vehicles using the clear fuel. This test is performed separately for each vehicle group and then the test results are added to give an overall test. For this waiver application, "start" will be interpreted as 1,000 miles since HiTEC 3000 is first introduced at that mileage.

(3) 1K versus 50K test. This is similar to test 2. The change in average emissions from start to 50,000 miles is computed for each combination of vehicle group and fuel. A sign test is performed by determining if the number of vehicle groups for which the change is greater using the additive is statistically significant. A Mann-Whitney test is also performed using the observed changes for each vehicle; this test determines whether, on average, the change in emissions for vehicles using the additive is higher than for vehicles using the clear fuel. This test is performed separately for each vehicle group and then the test results are added to give an overall test.

(4) <u>Integrated emissions test</u>. The data for each vehicle are averaged to give the emission rate at each mileage test point. A polygonal curve is then drawn through those points. The area under that curve and above the initial (1,000 miles) level estimates the total emissions above initial levels in grams for that vehicle. To allow comparisons with other statistical results, the total emissions increase is divided by the accumulated mileage to express the increase in grams per mile. These estimates are also averaged to give estimates of the average emissions increase for each combination of vehicle group and fuel. As in statistical test 2, a sign test and Mann-Whitney test are performed to determine if the increases tend to be greater when the additive is used.

(5) <u>Linear regression slopes test</u>. The additive fails this test for a particular vehicle group if the slope of the fitted regression line for the fuel additive exceeds the slope for the clear fuel by a significant amount (determined by a t test). This would mean that the average emissions for the fuel additive increase at a faster rate. The additive fails the overall test for all vehicles if the slope for the additive is higher for significantly many vehicle groups.

(6) <u>Deterioration factors test</u>. For each combination of vehicle group and fuel, a regression line is used to calculate the ratio of the predicted mean emissions at 50,000 miles to the predicted mean emissions at 4,000 miles. This ratio is termed the deterioration factor (DF) and is defined in 40 CFR 86.088-28(a)(4)(i)(B). For each vehicle group, the additive fails this test if the DF for the waiver fuel exceeds the DF for the clear fuel. The fuel additive fails the overall test for all vehicles if a significant number of vehicle groups fail the test.

(7) <u>Violation mileage test</u>. The violation mileage, the mileage at which the theoretical average emissions reaches the standard, is found for each combination of vehicle group and fuel using the fitted regression lines. If the estimated emissions exceed the standard at 0 miles, the violation mileage is 0. If the estimated emissions remain below the applicable standard over the useful life of the vehicle group (0 to 50,000 miles), the

violation mileage is 99,000 miles (corresponding to no violation). The additive fails this test for a vehicle group if the violation mileage occurs sooner in the vehicles using the additive fuel. The additive fails the overall test for all vehicles if a significant number of vehicle groups fail the test.

(8) Maximum percentage of vehicles failing standard test. For each combination of vehicle group and fuel at each mileage, the average percentage of vehicles failing the emissions test is estimated. This estimation is valid if one assumes that the regression line gives the mean emissions at that mileage and that variation about that regression line follows a normal distribution (bell-shaped curve). The estimated "maximum percentage" over all mileages from 0 to 50,000 is then found. This maximum percentage will be achieved at 50,000 miles if the slope is positive, and at 0 miles if the slope is negative. If this maximum percentage for the additive-fueled vehicles is greater than for the clear-fueled vehicles, the conclusion is that, for the particular vehicle group considered, more vehicles will fail the standard over their lifetimes if the additive is used. An overall test for all vehicles is performed by determining if the number of groups with an increased "maximum percentage" failure rate is statistically significant.

If after conducting the above eight tests a fuel or fuel additive demonstrates a statistically significant adverse emissions effect, the EPA has applied a ninth test to evaluate the impact of this effect on compliance with applicable emission standards. This pivotal test evaluates whether the adverse emissions effect "causes or contributes" to a failure of a vehicle to meet the emission standards for which it was certified. As described by the EPA, this test computes the estimated percentage failure rate for each combination of vehicle group and fuel by the same method as test 8. If at any mileage point the percentage failure rate for the additive fuel exceeds 10 percent and exceeds the percentage failure rate of the clear fuel, then the additive is presumed to cause or contribute to the failure of vehicles in that vehicle group to meet emissions standards. A sign test is used to determine if this "cause or contribute" occurs for a significant number of vehicle groups.

To determine whether the use of HiTEC 3000 has a statistically significant adverse emissions effect or causes or contributes to the failure of emission control systems or devices to meet applicable emission standards, all of the above statistical tests were performed and evaluated in this application. In addition, the large and concise data set generated by Ethyl's test program has provided the opportunity for the modification of the above tests as well as for the application of additional statistical methods. These modifications and additional tests are discussed in greater detail later in this section.

The EPA has recognized that the cause-or-contribute standard established by Section 211 (f)(4) does not require a waiver applicant to demonstrate that the fuel additive will not cause any increase in exhaust emissions.[7] Rather, the applicant need only demonstrate that the fuel additive does not cause or contribute to a failure of vehicles to meet emission standards.[8] For this reason, the EPA's statistical tests have been designed to document any negative directional or adverse effects caused by the introduction of the fuel additive. The questions of interest under the applicable legal standard are whether the addition of HiTEC 3000 to Howell EEE causes the tailpipe emissions generated in a long-term durability test to differ from those generated from the use of Howell EEE alone, and, if a difference does exist between the emissions from these two fuel types, whether the use of HiTEC 3000 causes a statistically significant adverse effect that will cause or contribute to the failure of a vehicle to meet applicable emission standards. For each of the statistical tests conducted as part of this waiver, with the notable exception of the initial emissions test, a one-tailed approach was therefore applied. Because the statistical tests are conducted in this manner, any beneficial effects of HiTEC 3000 will not be statistically detected. Though the quantitative results reported in the next section show substantial reductions in NO_x and CO emissions with the use of HiTEC 3000, no tests were conducted to declare the statistical significance of these benefits.

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7 Motor Vehicle Manufacturers Association of U.S. v. E.P.A., 768 F. 385, 390 (D.C. Cir. 1985).

8 MVMA v. E.P.A., 768 F. at 390.

In the initial emissions test the question that must be answered is whether an initial difference in emissions exists. The direction of any difference, if one exists, is unimportant. To answer this question, a two-sided statistical approach, which documents statistically significant differences in either direction, is applicable.

In addition to the determination of a one-tailed/two-tailed statistical approach, a confidence level must be established for reviewing the test results. The establishment of a confidence level is important because we wish to know how confident we can be that failure of a statistical test is due a HiTEC 3000 effect as opposed to random chance. In the 1978 waiver application for HiTEC 3000, the EPA applied a 90 percent confidence level to the submitted data. This level would suggest that, even with no additive effect, on average one would expect to see statistically significant effects in 1 out of 10 statistical tests. In the present waiver application we use a larger number of statistical tests than used by the EPA for the 1978 application. This allows one to look very closely at the effects of HiTEC 3000, insuring that observed failures (or passes) are due to the additive itself and not random chance. Because of the large number of statistical tests performed, the use of a confidence level higher than 90 percent is required in this application to adequately document the HiTEC 3000 effects. For that reason, a 95 percent confidence level was established for determining an adverse effect. The use of this 95 percent level implies that if no HiTEC 3000 effect exists, a failure will only be seen in 1 out of 20 statistical tests on average.

In applying the EPA statistical tests to the Ethyl fleet data, in many cases a sign test is performed to determine if the number of models for which an adverse effect was observed is statistically significant. Since there are eight models in the Ethyl fleet, and since a 95% confidence level (5% significance level) is used throughout our analyses (in view of the comments in the last paragraph) it follows that the sign test is failed if either seven or eight models show an adverse effect. This is because the probability of seven or more pluses out of eight is less than 5 percent, if pluses and minuses are equally likely. For the initial emissions test there is an exception because this test warrants a two-tailed approach (as discussed above). Therefore, either zero or eight initial differences will have a plus sign if the initial difference sign test is failed.

Note that the number of models used in the sign test is smaller than eight if there are models for which there is no difference between the fuels. In such cases the number of adversely affected models required for failure of the statistical tests will be less than seven.

EPA STATISTICAL TESTS FOR CERTIFICATION

Congress has defined the procedures required of all automobile manufacturers who market vehicles in the United States (Clean Air Act, Section 206). Among these procedures is the requirement that a manufacturer must obtain a "certification" from the EPA Administrator demonstrating that its vehicles will meet applicable emission standards during the useful life of the vehicles.

This requirement is of particular importance to applicants for fuel or fuel additive waivers because under Section 211(f) of the Clean Air Act, an applicant must show that the use of the fuel or fuel additive "will not cause or contribute to a failure of any emission control device or system (over the useful life of any vehicle in which such device or system is used) to acheive compliance by the vehicle with the emission standards with respect to which it has been certified pursuant to Section 206."[9] In addition, the EPA has stated (43 Fed. Reg. 11259) that "it is essential that test data provide a reliable basis for comparison with the conditions under which vehicles are certified pursuant to Section 206 of the Clean Air Act." Because of the integral role that the certification requirements play in the waiver process, some mention should be made of the certification test procedures used in the statistical analysis for this application.

Of primary interest to this analysis and the application of the EPA's statistical tests is the development of the deterioration factors used to evaluate the decrease in an emission control system's efficiency over the useful life of a vehicle (defined in the Clean Air Act as "a period of use of five years or of fifty thousand miles (or the

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9 42 U.S.C. §7545.

equivalent), whichever first occurs."[10] Although the method by which an automobile manufacturer accumulates the necessary data to derive the deterioration factor for each vehicle has been modified over the years, the basic calculation remains the same.

As originally developed by the EPA, the deterioration factor is the ratio of interpolated exhaust emissions at 50,000 miles over the interpolated exhaust emissions at 4,000 miles. The interpolated values are derived from fitting the best straight line to the actual exhaust emission data at the various testing mileage points using standard statistical analysis. After the deterioration factor for a particular vehicle model has been calculated, the EPA can then determine whether a vehicle will meet applicable emission standards for a particular pollutant by multiplying actual or estimated emissions data for 4,000 miles by the deterioration factor. Only then is a vehicle group certified by the EPA for sale in the United States.

DISCUSSION OF STATISTICAL ASSUMPTIONS

The initial emissions test, the seven adverse-effects tests, and the cause-or-contribute test were conducted using the data set ETHYL4S2. In conducting these tests and the modified tests discussed below, assumptions had to be made regarding the type of regression model that should be used for analysis, whether the vehicle means were equal or unequal, and whether the variability in emissions were consistent or inconsistent across mileages or fuels.

The EPA tests can be divided into four different types: the initial emissions test, the adverse-effects tests based on the raw data, the adverse-effects tests based on fitting a regression model to the data, and the cause-or-contribute test. A linear regression line calculated in the initial analyses of the 50,000 mile data was used in the four adverse-effects tests based on regression analysis and the cause-or-contribute test. As will be discussed in greater detail later in this section, a linear regression model was used primarily because of its application in previous waiver applications. For purposes of consistency with previous applications and because of the

[10] 42 U.S.C. §7521(d)(1).

EPA's use of the linear regression model in certification procedures, its use in analyzing the 50,000 mile data appeared to be warranted. In addition, linear regression results were required for input into EPA's MOBILE4 computer model used in the air quality studies (see Appendix 5). However, we repeated the 50,000 mile data regression analyses based on quadratic regression models, which in most cases fit the data statistically significantly better (Attachment C).

The second assumption is that the mean emissions for each individual vehicle is the same as that for all vehicles in the same vehicle group using the same fuel. If the mean emissions are equal, then all tests on all vehicles in that group/fuel combination can be averaged. If the mean emissions are unequal, an average of all emissions must be calculated for each individual vehicle and then for the group/fuel combination. Since the statistical tests were mainly carried out on ETHYL4S2, which has two tests per vehicle for most mileage intervals, the estimated mean emissions are in most cases the same under both assumptions. The estimates of emission variances are, however, affected by whether or not we make the assumption of equal vehicle means.

The third assumption is that the variance of emission test observations does not depend on mileage, although usually it does depend on vehicle model, fuel type, and pollutant. As can be seen by reviewing the data plots in Attachment B, there is no apparent pattern in the variability of observed emissions as mileage increases up to 50,000 miles.

An important question is whether variances across fuels for each vehicle model group and pollutant are equal. When the variance in emissions for each pollutant, vehicle model, and fuel combination is computed, there is no clear evidence that the variance is either reduced or increased consistently across models when clear fuel is replaced with HiTEC 3000. In many cases, however, the variances for the two fuels are statistically significantly different. Almost the same results are obtained when the statistical tests are carried out assuming unequal variance. (A mathematical explanation of this phenomenon is included in Attachment C).

SAI MODIFICATIONS TO EPA 50,000 MILES TESTS

The use of nonparametric tests (sign test and Mann-Whitney test) limits to some degree the probability of statistically detecting a difference in emissions if in fact a difference exists. Further, the sign test is based solely on calculating two numbers, one for each fuel. If the waiver fuel value is larger, the fuel effect is adverse for a given vehicle group regardless of the magnitude of the difference. For example, if the deterioration factor of the waiver fuel is 1.60 and the deterioration factor for the clear fuel is 1.59 for a given vehicle model group, then the waiver fuel will fail the test for that group. Obviously, the magnitude of the difference in this case could hardly be termed a practically significant effect. Thus the sign test has a high probability of showing an adverse effect for a given vehicle group even if the actual effect is either beneficial or not practically significant. Similar remarks apply to the Mann-Whitney tests. In general, the use of these tests does not take full advantage of the information available in the data. In addition, the overall tests that combine results from all of the vehicle models inherently assume that all models are equally represented in the national fleet and do not take into account the important issue that some model types are much more prevalent than others.

To be consistent with the EPA's previous approach in evaluating the potential effects of HiTEC 3000 on emission control systems, the initial emissions test, the seven adverse-effects tests, and the cause-or-contribute test were performed using the evaluation methods discussed above. However, in an attempt to enhance the statistical power of these tests to detect any differences if they exist, the following modifications were also performed in most cases.

1. The EPA's nonparametric tests (Mann-Whitney rank sum and sign of the difference tests) were also analyzed by an appropriate parametric test.

2. Tests based on linear regression were also analyzed by analogous tests based on quadratic regression.

3. Weighted averages over vehicle model groups using actual 1988 percentage sales figures were analyzed.

Complete details on these parametric tests are contained in Attachment C.

SAI ADDITIONS TO EPA 50,000 MILE TESTS

Since the data set is large (approximately 1700 emissions tests) and mileage was accumulated over a wider range than ever previously evaluated by the EPA in a waiver application, additional statistical tests could be performed to determine whether HiTEC 3000 causes or contributes to the failure of emission control systems to meet applicable emission standards. These tests are important not only because of their ability to distinguish statistically significant effects from the use of this product in unleaded gasoline, but also because they address basic questions concerning the appropriate statistical models to be used in long-term vehicle studies.

The first additional test involves the analysis of the mean HiTEC 3000 effect for mileages between zero and 50,000 miles. This approach is useful in determining any practical emissions effect of HiTEC 3000 because it looks only at the data generated in the test program as opposed to a statistical regression model. In this analysis the total emissions (in grams) over the interval from 1,000 to 50,000 miles are estimated for each vehicle and pollutant. The mean emissions for each test interval (1,000, 5,000, 10,000,...50,000 miles) is plotted against the mean test mileage and these points are joined by straight lines. The resulting polygonal curve estimates emissions in grams per mile as a function of mileage for that vehicle and pollutant. Therefore, the area under the curve estimates the total emissions in grams over the 49,000 mile accumulation for that vehicle. For convenient comparisons we divide the area by the accumulated mileage to estimate the average emissions in grams per mile. The results are averaged across vehicles and models and weighted according to 1988 sales. The approach taken in this analysis is exactly the same as the procedure used in SAI's application of the EPA's integrated emissions test except that the initial average emissions levels are not subtracted out.

It should be noted that the results obtained in the above analyses of the mean effect do not take into account the fact that the initial emissions levels of the vehicles selected for the HiTEC 3000 group differ from the levels for the clear-fueled vehicles. Since any initial difference cannot be a HiTEC 3000 effect and yet is expected to persist for the lifetime of the vehicles, it is reasonable to subtract the initial difference from the estimated HiTEC 3000 effect. Otherwise a difference at higher mileages due primarily to initial differences would be wrongly interpreted as a HiTEC 3000 effect. The initial difference is estimated by subtracting the weighted average emissions for the clear-fueled vehicles at 1,000 miles from the weighted average emissions for the HiTEC 3000-fueled vehicles at 1,000 miles. Complete results for the mean HiTEC 3000 effect with and without an adjustment for the initial differences between the vehicle groups are shown in Section 4 of this report and in Attachment D.

The second addition to the EPA's analysis methods is to use quadratic regression curves in applying the regression based tests. Historically, the EPA has based much of its statistical analysis of automobile emissions on a simple linear regression model. This model is derived by fitting the best straight line to the mean emissions data at various test mileage points using standard statistical techniques. In particular, this modeling approach was used by the EPA to evaluate Ethyl's 1978 waiver application for HiTEC 3000 and continues to be used for calculating deterioration factors for certification testing.

Once all mileage had been accumulated in this program (75,000 miles), a visual observation of the plotted raw data indicated that a linear regression model might not be the most appropriate model for statistically evaluating the effects of HiTEC 3000. As can be seen in the plots in Attachment B, exhaust emissions appear to be generally linear from 0 to about 50,000 miles, but from 50,000 to 75,000 miles the slopes for each pollutant group tend to flatten.

In order to select the most appropriate regression model for the total accumulated data, statistical tests were conducted and comparisons of the "goodness of fit" of both linear and quadratic models were made. Based on this comparison, a quadratic regression model was shown to fit the data better. The improvement in fit was statistically significant for both the 50,000 mile and 75,000 mile data in most cases. The statistical tests used in this determination are described in Attachment C.

For the 50,000 mile analysis, we therefore repeated the various EPA and SAI-modified regression tests using quadratic regressions rather than linear regressions. The quadratic regression tests, described below for the 75,000 mile analysis (and described in detail in Attachment C) are similar in principle to the linear regression tests. The main difference is that the slopes comparison is carried out at different mileages because the quadratic model assumes that the slope (deterioration rate) varies with mileage. Since the fit of the linear regression model is relatively good for the 50,000 mile data, as opposed to the 75,000 mile data, the results of the quadratic regression tests do not differ very much from the linear regression tests for the 50,000 mile data.

75,000 MILE EXTENSIONS OF 50,000 MILE TESTS

The decision to extend the mileage accumulation phase of the waiver program to 75,000 miles required that the tests previously applied by the EPA be reviewed. This review led to extensions or certain modifications in a number of the EPA's adverse-effects tests as well as the cause-or-contribute test. It also allowed for the application of additional statistical tests to the complete 75,000 mile data set. Given the size of the improvement in fit between the linear and quadratic models for the 75,000 mile data, the regression tests for the 75,000 mile data were based on quadratic models only. In addition, where appropriate, the Mann-Whitney and sign of the difference tests were supplemented by parametric tests, and weighted averages over vehicle model groups using 1988 percentage sales figures were also applied to the 75,000 mile data set. This is consistent with the approach to evaluating the 50,000 mile data. The following modifications were made to the initial emissions, adverse-effects, and cause-or-contribute tests, for both the EPA nonparametric tests and the SAI parametric versions. These tests were applied to data set ETHYL4S2.

1. Initial emissions test. The accumulation of 75,000 miles and the resultant data set obviously have no effect on the initial emission levels. For this reason, the initial emissions test was not performed on the additional data.

2. 1K versus 5K test. The accumulation of 75,000 miles has no effect on the test start through 5,000 miles. Therefore, this test was not run a second time.

3. 1K versus 75K test. This test is similar to the 1K versus 50K test with the exception that 75,000 mile data is used instead of 50,000 mile data.

4. Integrated emissions test. This test is analagous to that developed and used by the EPA but uses the complete 75,000 mile data instead of the 50,000 mile data.

5. Slopes test. In a quadratic regression model the slope of the fitted regression curve changes with mileage. For this reason it would not be possible to determine a single slope for each vehicle group. Therefore, slopes are calculated at 25,000, 50,000, and 75,000 miles for each vehicle group and then compared by fuel type. The additive fails this test for a particular vehicle group if the slope of the fitted quadratic regression curve for the waiver fuel exceeds the slope for the clear fuel by a significant amount (as determined by a t test). The additive fails the overall modified test if the waiver fuel slope is higher for significantly many vehicle groups.

   Since the MOBILE4 input requires separate linear regressions applied to the data before and after 50,000 miles (rather than a single regression model) a linear regression model was fitted to the data from 55,000 to 75,000 miles. The EPA linear regression slopes test was applied to these linear regressions.

6. Deterioration factors test. A quadratic regression curve is used to redefine the deterioration factor as the ratio of the predicted mean emissions at 75,000 miles to the predicted emissions at 4,000 miles for each combination of vehicle group and fuel. The analysis parallels the 50,000 mile analysis.

7. <u>Violation mileage test</u>. Using the fitted quadratic regression curves, the violation mileage at which the theoretical average emissions reaches the standard is found for each combination of vehicle group and fuel.

8. <u>Maximum percentage of vehicles failing standard test</u>. A quadratic regression curve is calculated for each combination of vehicle group and fuel. At each mileage the average percentage of vehicles failing emissions tests is estimated and the maximum percentage over all mileages from the start to 75,000 miles is then found.

9. <u>Cause or Contribute test</u>. The 50,000 mile version is extended to 75,000 miles by changing the linear regression model to a quadratic regression model and by comparing estimated percentage failures at each mileage from 0 to 75,000 miles.

10. <u>Test of quadratic coefficient</u>. A quadratic coefficient is calculated for each combination of vehicle group and fuel. This coefficient is defined as the multiple of mileage squared and is one-half the rate of change of the quadratic regression slope. The additive fails this test for a particular vehicle group if the quadratic coefficient for the waiver fuel exceeds the coefficient for the clear fuel by a significant amount (determined by a t test). The additive fails the overall test if it fails the test for a significant number of vehicle groups.

4 RESULTS OF ANALYSIS OF COMPOSITE EMISSIONS

In the previous sections of this appendix the statistical basis for Ethyl's HiTEC 3000 waiver application was reviewed. In Section 2 the testing program was described, including a discussion of the waiver fleet, the general procedures followed during mileage accumulation and emissions testing, and the rationale for the data sets analyzed. In Section 3 the statistical methods developed by EPA for previous waiver submissions were described. Because the data generated in support of this waiver request are from a well-designed emissions testing program, many of the EPA tests could be enhanced and other, more powerful, statistical techniques could be applied.

This section presents the results of the statistical tests and analyses. To aid the reader in interpreting these results, the significance of the adverse-effects and cause-or-contribute tests, the modifications made to these tests, and the additional tests are summarized. **Tables are presented in the text showing the relevant results for the weighted averages across vehicle model groups.** Detailed results (including model-specific results) are provided in two complete sets of tables found in Attachments D (50,000 mile analyses) and E (75,000 mile analyses).

WEIGHTED AVERAGE EMISSIONS

Figures 4-1 through 4-3 show the plotted 75,000 mile raw data (data set ETHYL4S2) for HC, CO, and NO_X and indicate the current federal standards of 0.41, 3.4, and 1.0 g/mile, respectively. These plots were developed by taking the average emissions for each fuel for each vehicle group and weighting them based on 1988 sales figures.

In viewing these plots, a number of significant points can be made. In general, it is apparent from the weighted averaged data that both the clear and HiTEC 3000

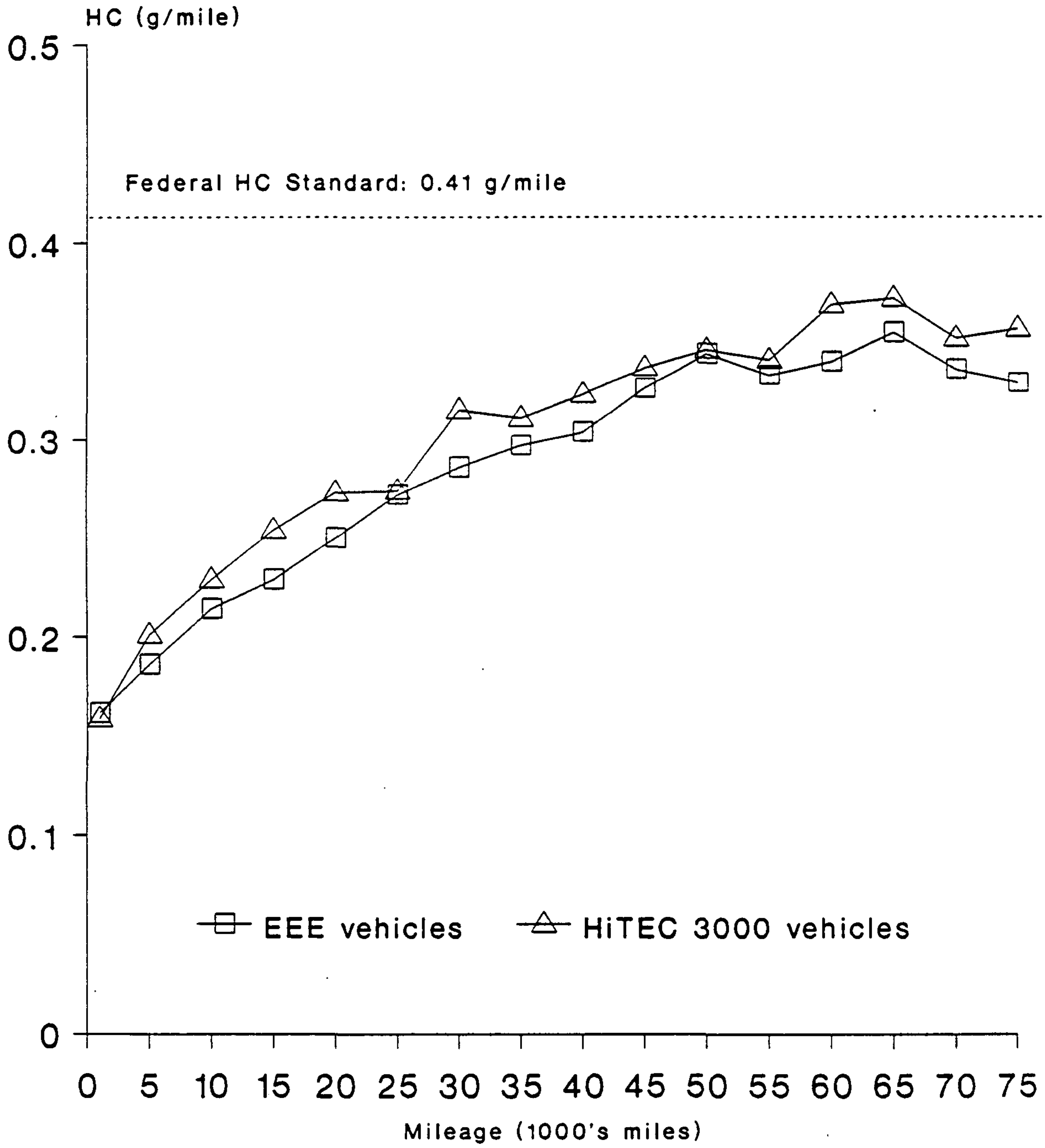

FIGURE 4-1. Weighted average hydrocarbon tailpipe emissions (data set ETHYL4S2).

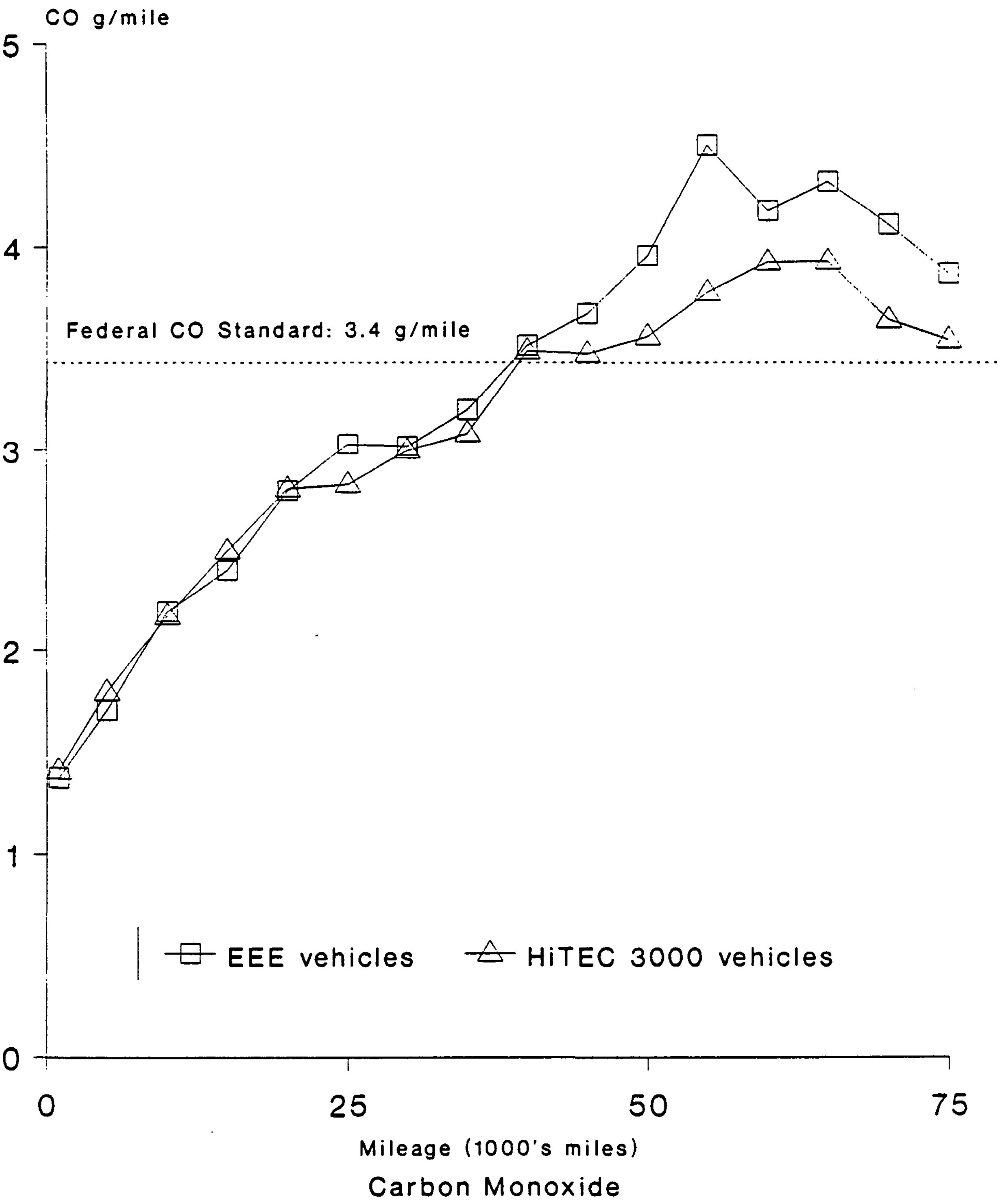

FIGURE 4-2. Weighted average carbon monoxide tailpipe emissions (data set ETHYL4S2).

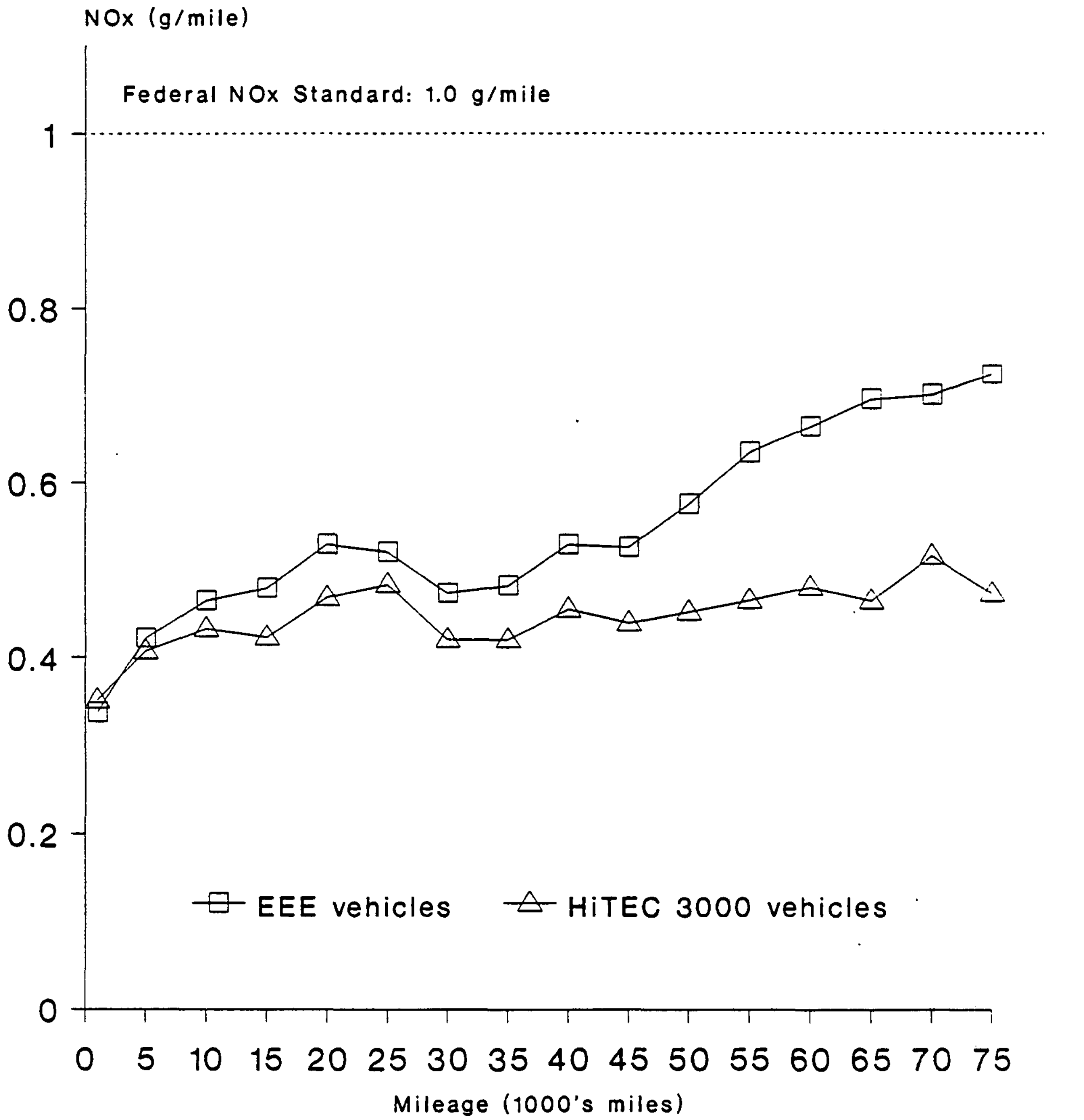

FIGURE 4-3. Weighted average nitrogen oxide tailpipe emissions (data set ETHYL4S2).

vehicle groups meet current 50,000 mile emission standards for both HC and NO_x and remain below the 50,000 mile standard at 75,000 miles. This would imply that for the waiver fleet, which represents 53 percent of 1988 U.S. sales, the use of HiTEC 3000 does not cause or contribute to the failure of any emission control system to meet HC and NO_x standards. Additionally, the vehicles fueled with HiTEC 3000 clearly show an improvement in CO emissions as compared to the clear-fuel vehicles beginning at 40,000 miles. Although both vehicle groups do fail to meet the current federal CO emission standard of 3.4 g/mi, the plotted results suggest that the long-term use of HiTEC 3000 results in CO emissions reductions and does not cause or contribute to the failure of an emission control system to meet CO standards.

From the earliest stages of the mileage accumulation program, HiTEC 3000 demonstrates a beneficial and lasting effect on NO_x emissions. This improvement begins very shortly after the initial addition of the additive; although the vehicles assigned to HiTEC 3000 have slightly higher initial (1,000 miles) emissions, they have lower emissions at the first testing interval following the addition of the additive (5,000 miles). The beneficial effect increases as mileage accumulates, and at 25,000 miles NO_x emissions are decreased on average by 0.04 g/mi. The benefits from the use of HiTEC 3000 in controlling NO_x continues with additional mileage. At 50,000 miles, NO_x emissions are reduced by 0.12 g/mi in those vehicles fueled with HiTEC 3000 and are further decreased to 0.25 g/mi when measured at 75,000 miles. As emission control strategies take into greater account the effects of NO_x on air quality, the improvement demonstrated by HiTEC 3000 must be considered.

Figure 4-2 shows that the use of HiTEC 3000 does not cause or contribute to the failure of a vehicle to meet current CO emission standards. Up to 40,000 accumulated miles there is no apparent effect of HiTEC 3000 on emission rates. Past 40,000 miles, however, HiTEC 3000 shows a beneficial impact on emissions. At the conclusion of 50,000 miles of accumulation the weighted averaged data show that the vehicles fueled with HiTEC 3000 have 0.40 g/mi less CO emissions than those fueled with Howell EEE alone. This effect on CO emissions continues for the remainder of the test program, with a 0.33 g/mi decrease observed at 75,000 miles.

As can be seen in Figure 4-1, the use of HiTEC 3000 does not cause or contribute to the failure of the waiver fleet to meet the current HC emission standard at either 50,000 or 75,000 miles. Although small increases in HC emission rates are observed, at 50,000 miles the vehicles fueled with HiTEC 3000 are 0.07 g/mi below the current federal HC standard of 0.41 g/mi.

Taken together in this straightforward manner, the plots of the averaged 75,000 mile raw data weighted by 1988 actual sales figures clearly show that the use of HiTEC 3000 in unleaded gasoline will not cause or contribute to the failure of emission control systems to meet the standards for which they were certified. Although this graphical examination of the effects of HiTEC 3000 is useful in gaining an overall perspective of the potential effects from the use of the product, the application of statistical tests defined by EPA and expanded in this study address more accurately the specific effects present.

As was mentioned in Section 3, the statistical tests applied to data set ETHYL4S2 are divided into four different types: the initial emissions test, the adverse-effects tests based on the raw data, the adverse-effects tests and modifications based on fitting a regression model to the data, and the cause-or-contribute test. In the presentation of the test results, each of the four test groups will be discussed separately. In addition, the results on those tests performed on the 50,000 mile data will be reviewed first followed by the 75,000 mile results.

INITIAL EMISSIONS TEST

As described in Section 3, the initial emissions test compares the emissions rate (in g/mi) between the HiTEC 3000-fueled vehicles and the clear-fueled vehicles at 1,000 miles. In developing this test, the EPA wanted to address the concern that an initial difference in the emission levels from waiver vehicles operated on different types of fuels could potentially mask a fuel effect. This would indicate that the EPA does not consider this test as a measure of any initial adverse effect but rather as a means of establishing initial differences that may exist between the two vehicle populations. In this program, all 48 test vehicles were assigned to a fuel type in a random manner at 1,000 miles. Although this selection was intended to insure that no bias was introduced into the assignment of the fuel types, Table 4-1 shows that there were some differences in the initial emission rates.

TABLE 4-1. Comparison of initial emission rates (g/mi).

	Cars to be Fueled by EEE	Cars to be Fueled by HiTEC 3000
HC	0.162	0.159
CO	1.38	1.41
NO_x	0.34	0.35

The statistical tests reported in Attachment D (pages D-1 to D-6) and summarized in Table 4-2 indicate that the initial differences in emissions between those vehicles fueled with HiTEC 3000 and those on clear fuel are not significant for HC and CO using either non-parametric or parametric tests. For NO_x, the use of a non-parametric rank sum test indicates that the initial difference is significant when vehicle means are assumed to be equal. Furthermore, the application of a parametric t test also indicates a significant difference if the assumption is made that vehicle means are not equal.

Although the issue of equal/not equal vehicle mean assumptions was raised and discussed in Section 3, the effect that this assumption has on the statistical results in this test requires that some mention again be made. Throughout the statistical study, data set ETHYL4S2 has been used as the main working data set. This data set excludes all standard emissions tests beyond the first two to insure that the variance calculations are not biased or unfairly weighted. However, a number of the statistical tests available for analyzing the potential effects of HiTEC 3000 in this waiver request do allow for the application of both equal and unequal vehicle mean emissions assumptions. In an equal vehicle mean emissions assumption, all tests on all

TABLE 4-2. Statistical analysis of 50,000 mile emissions data: results of initial emissions test. The table notes passes (P) and failures (F) for both EPA nonparametric (NPARM) and SAI parametric (PARM) tests.

Test Version	HC		CO		NO_x	
	NPARM	PARM	NPARM	PARM	NPARM	PARM
Equal car means	P	P	P	P	F	P
Unequal car means	P	P	P	P	P	F

vehicles within a group/fuel combination can be averaged and the variability of emissions determined about this common mean. When one assumes that the vehicle mean emissions are not equal, then an average of all emission tests for an individual vehicle must be calculated and then averaged across the group/fuel combination. The estimated variance between emissions for any given vehicle group/fuel combination will be larger under the equal vehicle mean emissions assumption.

NONREGRESSION ADVERSE-EFFECTS TEST RESULTS ON 50,000 MILE DATA

In reviewing the summary of results for the non-regression adverse effects tests on the 50,000 mile data (Table 4-3) it can be seen that HiTEC 3000 passes all non-parametric and parametric statistical tests except the 1K versus 5K test for HC, and the 1K to 50K integrated emissions test for HC. The significance of each of these individual tests will be discussed in more detail below.

1K Versus 5K Test

The 1K versus 5K test was developed to determine if an additive causes an increase in emissions during initial mileage accumulation. For this test, the average increase in emissions from 1,000 miles to 5,000 miles is calculated; the results are in Table 4-4.

TABLE 4-4. Change in emissions from 1,000 to 5,000 miles (g/mi).

	EEE	HiTEC 3000	HiTEC 3000 Effect (g/mi)
HC	+0.024	+0.041	+0.017
CO	+0.33	+0.39	+0.06
NO_x	+0.09	+0.06	-0.03

TABLE 4-3. Statistical analysis of 50,000 mile emissions data: results of nonregression adverse test effects. The table notes passes (P) and failures (F) for both EPA nonparametric (NPARM) and SAI parametric (PARM) tests.

	HC		CO		NO_x	
Test and Version	NPARM	PARM	NPARM	PARM	NPARM	PARM
1k versus 5k						
Equal car means	F	F	P	P	P	P
Unequal car means	F	F	P	P	P	P
1k versus 50k						
Equal car means	P	P	P	P	P	P
Unequal car means	P	P	P	P	P	P
Integrated emissions						
1k to 50k	F	F	P	P	P	P
5k to 50k	P	P	P	P	P	P

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The statistical tests applied to these averages (Attachment D) show that the use of HiTEC 3000 is not associated with a significant change in the CO or NO_x emissions from 1,000 miles to 5,000 miles. These results are consistent regardless of the vehicle means assumption made or the non-parametric/parametric test method used. In the case of HC, the results indicate that a small (0.017 g/mile) but statistically significant increase in emissions does occur. This implies that the use of HiTEC 3000 is associated with a short-term increase in HC emissions.

The analysis of emission changes from 1,000 miles to 5,000 miles does not imply that emissions are affected, either favorably or unfavorably, immediately after HiTEC 3000 addition. In response to Ethyl's 1978 waiver application, comments were received from the automobile manufacturers suggesting that HiTEC 3000 caused an instantaneous effect on tailpipe emissions. The EPA determined in their evaluation of the application that HiTEC 3000 "is expected to affect vehicle emissions over a period of time rather than 'instantaneously.' Therefore, conventional back-to-back emission tests of the same car on different fuels would not be an appropriate test method to evaluate HiTEC 3000 effects."[11] In this waiver program, however, Ethyl did conduct tests on a number of vehicles to confirm the EPA's previous conclusions that this instantaneous effect does not exist. The results of these tests are contained in Appendix 2C and show that HiTEC 3000 does not have an instantaneous effect on emissions.

1K Versus 50K Test

The approach used in this test and the intent of this test are similar to that of the 1K versus 5K test. The average increase in emissions from 1,000 miles to 50,000 miles is calculated and the resultant values for each fuel type are compared; these increases are shown in Table 4-5. This test was developed to determine whether the

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increase in emissions over a long-term mileage accumulation program is higher on average for the additive-fueled vehicles than the clear-fueled vehicles.

TABLE 4-5. Change in emissions from 1,000 to 50,000 miles (g/mi).

	EEE	HiTEC 3000	HiTEC 3000 Effect (g/mi)
HC	+0.182	+0.187	+0.005
CO	+2.57	+2.15	-0.04
NO_x	+0.24	+0.10	-0.14

The statistical analysis of the long-term changes in emissions (Attachment D, pages D13-D18) shows that the use of HiTEC 3000 is not associated with a significant effect on any of the three regulated pollutants using either nonparametric or parametric test methods. In addition, the changes that occur remain insignificant regardless of the vehicle mean assumption made.

This test is of particular interest to this application because it puts the short-term effect of HiTEC 3000 on HC emissions in greater perspective. The results of the 1K versus 50K test coupled with the fact that average emissions for HC (as seen in Figure 4-1) do not fail federal emission standards indicate that the use of HiTEC 3000 is not associated with a long-term adverse effect on emission control systems.

Integrated Emissions Test

The integrated emissions test differs from the 1K versus 50K test. In this test, the total emissions above initial levels accumulated over the entire mileage program are calculated as opposed to comparing the average emissions at only two mileage points (1000 miles and 50,000 miles) as in the previous test. This is accomplished by averaging the data for each vehicle at each mileage point and drawing a polygonal curve through those points. The area under the curve (and above the initial level, i.e., 1,000 miles) estimates the total emissions above the initial level in grams for that vehicle. The total integrated emissions for each vehicle is then divided by the accumulated mileage (49,000 miles) to express the result in an emission rate as grams per mile.

TABLE 4-6. Integrated emissions above initial levels (g/mi) from 1,000 to 50,000 miles.

	EEE	HiTEC 3000	HiTEC 3000 Effect (g/mi)
HC	0.102	0.119	+0.017
CO	1.47	1.37	-0.10
NO_x	0.16	0.08	-0.08

The results shown in Table 4-6 and the statistical tests reported in Attachment D (pages D19-D21) clearly indicate that for both nonparametric and parametric test conditions HiTEC 3000 is not associated with a significant effect on the integrated CO or NO_x emissions. However, there is a small but statistically significant increase in HC emissions under either test method.

Because of the earlier observation that HiTEC 3000 was associated with a short-term increase in HC emissions, it is likely that this initial difference results in the failure of the integrated emissions test, since the initial HC difference in Table 4-1 and the integrated emissions difference in Table 4-6 are both 0.017 g/mi. To examine this further, the integrated emissions were recalculated assuming an initial level of 5,000 miles instead of 1,000 miles. Under this modified test, HiTEC 3000 passed both the nonparametric and parametric tests for all three pollutants; the weighted average results are shown in Table 4-7 and statistical tests are reported in Attachment D (pages D22-D24).

TABLE 4-7. Integrated emissions above initial levels (g/mi) from 5,000 to 50,000 miles.

	EEE	HiTEC 3000	HiTEC 3000 Effect (g/mi)
HC	0.086	0.087	+0.001
CO	1.25	1.09	-0.16
NO_x	0.08	0.03	-0.05

These results indicate that the failure of the HC integrated emissions test is attributable to the initial effect seen at 5,000 miles. That initial effect of 0.017 g/mi does not increase from 5,000 to 50,000 miles. In other words, there is an initial (1,000 to 5,000 miles) small adverse effect of HiTEC 3000 on the emission rates, but no additional adverse effect past 5,000 miles.

Average Effects Analysis

The average effects analysis is not a statistical method previously used by the EPA to evaluate HiTEC 3000. The average effect is calculated from the total integrated emissions between 1,000 miles and 50,000 miles for each vehicle; to derive an average emission in grams per mile, this total is divided by the accumulated mileage. This approach differs from the earlier integrated test because emissions are integrated above zero rather than above the emissions when the additive is first introduced.

In this analysis the treatment of any initial emissions difference is very important. This is because any difference that exists at the outset will be carried throughout the test program and unfairly bias the test results. As was observed in the initial emissions test, the random assignment of fuels to vehicles resulted in higher statistically significant NO_x emissions in those vehicles using HiTEC 3000 as compared to clear-fuel vehicles. For this reason, the HiTEC 3000 averages shown in Table 4-8 were calculated by scaling for the initial difference between HiTEC 3000 and Howell EEE. Although an initial difference was found to be statistically significant only for NO_x emissions, HC and CO emissions are also scaled for consistency of the analysis approach. The initial differences observed in Table 4-1 were -0.002 g/mi for HC, 0.03 g/mi for CO, and 0.02 g/mi for NO_x.

TABLE 4-8. Average effect of HiTEC 3000.

	Average Integrated Emissions, 1,000 to 50,000 Miles (g/mi)		HiTEC 3000 Effect (g/mi)
	EEE	HiTEC 3000	
HC	0.263	0.281	+0.018
CO	2.84	2.75	-0.09
NO_x	0.49	0.42	-0.07

The table shows average decreases of 0.09 g/mi CO and 0.07 g/mi NO_x over the useful life of the vehicle. The difference calculated for HC indicates a slight increase in the average emissions in those vehicles fueled with HiTEC 3000. This increase is nearly equal to the short-term 1,000 to 5,000 mile increase for HC shown in Table 4-4. The implication again is that after a small initial increase, there is no effect of HiTEC 3000 on emissions over the useful life of the vehicle.

In evaluating the results obtained in the adverse-effects tests based on the raw data, the use of the more powerful parametric tests raises a question as to the degree of measurable difference that can be statistically observed between the two fuel types. This question is of particular importance in putting any observed increase in emissions in context from a practical as opposed to a statistical point of view.

To address this question, calculations were carried out on the integrated emissions test and the 1K versus 5K test. The results of these calculations are that if HiTEC

3000 causes an increase in emissions of only 0.011 g/mi, then this increase can be statistically detected 50 percent of the time. The implication of these calculations is that a very small difference in HC emissions is likely to be detected because of the amount of data available and the powerful statistical methods employed.

LINEAR REGRESSION-BASED ADVERSE-EFFECTS TESTS ON 50,000 MILE DATA

As described in Section 3, a linear regression model was used for the initial analyses of the waiver fleet data. This was due to the fact that the EPA had previously applied this type of regression model in earlier waiver applications and continues to use a linear model for certification of automobiles. In addition, this simple model was applied because linear regression results were required for input into EPA's MOBILE4 computer model for evaluating the effects of HiTEC 3000 on air quality. Further discussion on the methods of incorporating these linear regression results into MOBILE4 is contained in Appendix 5.

The linear regression-based adverse-effects test results are summarized in Table 4-9. As can be readily seen, HiTEC 3000 passes all tests for each of the regulated pollutants for both non-parametric and parametric conditions. Further discussion of each test is provided below.

Linear Regression Slopes Test
Linear Regression Deterioration Factors Test

The linear regression slopes test, which calculates the vehicle deterioration rate, and the deterioration factors test are similar in that they both rely upon a fitted regression line that determines an emission slope over mileage. The deterioration rate is defined as the slope of the regression line while the deterioration factor is the fitted (from the regression model) 50,000 mile emission rate divided by the fitted 4,000 mile emission rate.

TABLE 4-9. Statistical analysis of 50,000 mile emissions data: results of linear regression-based adverse-effects tests. The table notes passes (P) for both the EPA nonparametric (NPARM) and SAI parametric (PARM) tests.

Test	HC		CO		NO_x	
	NPARM	PARM	NPARM	PARM	NPARM	PARM
Linear regression slopes (deterioration rate) test	P	P	P	P	P	P
Linear regression deterioration factors test	P	P	P	P	P	P
Violation mileage test	P	P	P	P	P	P
Maximum percentage of vehicles failing standard test	P	P	P	P	P	P

TABLE 4-10. Comparison of deterioration rates and deterioration factors.

	Deterioration Rate/ 10,000 Miles		Deterioration Factor	
	EEE	HiTEC 3000	EEE	HiTEC 3000
HC	0.035	0.036	1.77	1.73
CO	0.48	0.42	2.29	2.07
NO_x	0.03	0.01	1.45	1.20

The calculated deterioration rates and deterioration factors for all three regulated pollutants are shown in Table 4-10 above. The statistical comparison and testing shown in Attachment D (pages D37-D42) indicate that HiTEC 3000 demonstrates no adverse effect for any pollutant. This is an important conclusion in light of the EPA's use of deterioration factors in vehicle certification tests, and the use of deterioration rates in the estimation of fleet emissions calculated by EPA's MOBILE4 model.

The question of whether the addition of HiTEC 3000 would have affected the certification of any of the eight model groups in the waiver fleet could be decided by dividing the deterioration factor for HiTEC 3000 by the deterioration factor obtained for Howell EEE. The resulting ratio would provide a measure of the incremental difference in emissions when using the HiTEC 3000 additive. As can be seen in Table 4-10, the deterioration factor for HiTEC 3000 is less than that for Howell EEE for all three pollutants, and therefore the calculated ratio would be less than one in all cases. Because of this, the 50,000 mile emission rates that would be calculated by multiplying the ratio by the 50,000 mile certification emission rates for HC, CO, and

NO_x will always be less than the emissions currently certified for 50,000 miles.[12] The results of this calculation imply that all eight model groups would have been certified as complying with applicable emission standards even if they used fuel containing HiTEC 3000.

Violation Mileage Test

In this test, the mileage point at which the theoretical average emissions violate the applicable standard is estimated for each vehicle group/fuel combination using the fitted regression lines. The additive fails this test for a vehicle group if the violation mileage is earlier using the additive fuel. The additive fails the overall test if it fails the test for a significant number of vehicle groups. In Attachment D (pages D43-D45), the results for the individual vehicle groups are presented, and the overall statistical test is performed for each pollutant. The results obtained when all vehicle groups are compared shows that HiTEC 3000 has no statistically significant adverse effect for any of the regulated pollutants, i.e., that violations do not occur at earlier mileages with the use of HiTEC 3000.

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[12] The 50,000 mile certification exhaust emissions (g/mi) of the eight model groups in the waiver fleet are:

Model Group	HC	CO	NO_x
C	0.23	2.50	0.16
D	0.33	1.80	0.60
E	0.14	3.30	0.50
F	0.23	1.60	0.40
G	0.17	2.00	0.24
H	0.29	3.00	0.74
I	0.26	2.60	0.24
T	0.19	0.41	0.50

Maximum Percentage of Vehicles Failing Standard Test

For this test, the average percentage of vehicles failing an emissions test is estimated for each vehicle group/fuel combination at each mileage point, based on the linear regression fit. Once the average percentage of vehicles in each group/fuel combination is determined, the estimated maximum percentage over all mileages from 0 to 50,000 is then calculated. Since this test as developed by the EPA is based on a linear regression model, if the slope is positive, then the estimated percentage of vehicles failing the standard increases with mileage, and so the mileage at which the maximum percentage of vehicles is achieved is at 50,000 miles. (See further details in Attachment C.)

This test compares the calculated maximum percentage for the clear-fueled vehicles with the HiTEC 3000-fueled vehicles and concludes that for a particular vehicle group the additive fails if the maximum percentage is greater for the additive-fueled vehicles than the clear-fueled. The results of this test (Attachment D, pages D46-D48) show that HiTEC 3000 passes for all three pollutants and therefore would not cause a greater percentage of vehicle failures to meet applicable emission standards over 50,000 miles.

Quadratic Regression-Based Adverse Effects Tests on 50,000 Mile Data

Visual observation of the plotted raw data (Attachment B) indicated that a linear model may not be the most appropriate regression model for analyzing the entire data set and that a quadratic model might be more appropriate. This was confirmed in a number of statistical tests conducted to determine if the quadratic model provided better "goodness of fit" than the linear model for each fuel/model group combination. These tests are described and the results are reported by model group in Attachment D (pages D49 to D66). For most model groups, a quadratic model provided a better fit than a linear model for all three pollutants.

Modifications to EPA regression-based adverse effects tests for quadratic regression were described in Section 3. The quadratic regression-based adverse-effects test results are summarized in Table 4-11. In each of these tests the results duplicate the

TABLE 4-11. Statistical analysis of 50,000 mile emissions data: results of quadratic regression-based adverse-effects tests. The table notes passes (P) for both the EPA nonparametric (NPARM) and SAI parametric (PARM) tests.

Test	HC		CO		NO_x	
	NPARM	PARM	NPARM	PARM	NPARM	PARM
Quadratic regression slopes tests	P	P	P	P	P	P
Quadratic regression deterioration factors test	P	P	P	P	P	P
Quadratic coefficient test	P	P	P	P	P	P
Violation mileage test	P	P	P	P	P	P
Maximum percentage of vehicles failing standard test	P	P	P	P	P	P

findings obtained when a linear regression model was used to analyze the data (Table 4-9). That is, the use of HiTEC 3000 does not demonstrate an adverse effect on any regulated pollutant.

Quadratic Regression Slopes Test (deterioration rate)
Quadratic Regression Deterioration Factors Test
Quadratic Coefficient Test

In these tests, a curve for each pollutant, fuel, and model group is developed through the use of a quadratic regression model. The deterioration rate at any mileage point is then estimated as the slope of the regression curve at that mileage. The deterioration factor is the fitted (from the quadratic regression) 50,000 mile emission rate divided by the fitted 4,000 mile emission rate. The quadratic coefficient is defined as the rate of change in the deterioration rate and, if negative, implies that deterioration is slowing down. The results are shown in Table 4-12.

As can be seen in Table 4-12 and confirmed with statistical testing (Attachment D, pages D49-D60), HiTEC 3000 causes no adverse effect for any pollutant in regards to the 25,000 mile deterioration rate, 50,000 mile deterioration rate, quadratic coefficient, and deterioration factor. The quadratic coefficients are all negative, and those for HiTEC 3000 are equal to or less than those for the clear-fuel, indicating a faster decrease in deterioration rates relative to clear-fuel vehicles. These results are very important in evaluating the effect of HiTEC 3000 on emission control systems. For all three pollutants, the deterioration rates for Howell EEE and HiTEC 3000 are similar at 25,000 miles and substantially lower at 50,000 miles for HiTEC 3000. As was evidenced in the 1K versus 5K test, HiTEC 3000 was associated with a short-term adverse effect on HC emissions. The results from this analysis indicate again that the use of HiTEC 3000 has no additional adverse effect on HC emissions beyond 5,000 miles.

A comparison of the deterioration factors obtained through the use of a quadratic regression model (Table 4-12) shows that the deterioration factors for HiTEC 3000 are lower than the deterioration factors for Howell EEE for HC, CO, NO_x. This is

TABLE 4-12. Comparison of deterioration rates and deterioration factors based on quadratic regression. The deterioration rate at any mileage point is estimated as the slope of the regression curve at that mileage. The deterioration factor is the fitted (from the quadratic regression) 50,000 mile emission rate divided by the fitted 4,000 mile emission rate. The quadratic coefficient is the rate of change (decrease) of the deterioration rate.

		Estimated Deterioration Rate/ 10,000 Miles		Quadratic	Deterioration
		25,000 Miles	50,000 Miles	Coefficient	Factor
HC	EEE	0.035	0.021	-0.003	1.77
	HiTEC 3000	0.036	0.005	-0.006	1.73
CO	EEE	0.48	0.26	-0.04	2.30
	HiTEC 3000	0.42	0.10	-0.06	2.09
NO_x	EEE	0.03	0.00	-0.01	1.44
	HiTEC 3000	0.01	-0.02	-0.01	1.17

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similar to the comparison of deterioration factors obtained through the use of a linear regression model. If the ratio calculated by dividing the deterioration factor for HiTEC 3000 by the deterioration factor for Howell EEE is again multiplied by the 50,000 mile certification emission levels (see footnote 12), the resultant certification number would again be less than applicable standards.

Violation Mileage Test

As was seen in the violation mileage test using the linear regression model, HiTEC 3000 passes all tests for all three pollutants (Attachment D, pages D61-D63). This again shows that the use of HiTEC 3000 would not cause a vehicle to exceed applicable emission standards earlier than a clear-fuel vehicle.

Maximum Percentage of Vehicles Failing Standard Test

The results of this test (Attachment D, pages D64-D66) confirm the findings found previously when a linear regression model was used to analyze the data. The use of HiTEC 3000 does not result in a greater percentage of vehicles failing emissions standards.

CAUSE-OR-CONTRIBUTE TEST BASED ON 50,000 MILE DATA

If, according to the EPA, an additive shows a significant adverse emissions effect, then an additional test can be applied to address the impact of this effect on exhaust emissions on compliance with applicable emission standards. This additional test examines whether the adverse emissions effect "causes or contributes" to a failure of vehicles to meet applicable emission standards. As described by the EPA, this test is similar in design to the maximum percentage of vehicles failing the standard test. It differs by asking if, at any mileage point, the percentage failure rate for the additive exceeds 10 percent and exceeds the percentage failure rate for the clear fuel. If this occurs, the additive is presumed to cause or contribute to the failure of vehicles in that vehicle group to meet emissions standards. A sign test is used to determine if this "cause or contribute" effect occurs for a significant number of vehicle groups.

As for the maximum percentage of vehicles failing standard test, both a linear and quadratic regression model were used to evaluate the effects of HiTEC 3000. The results obtained using either regression model are the same: the addition of HiTEC 3000 does not cause or contribute to a failure to meet applicable standards (Attachment D, pages D67-D72).

The results obtained in the seven adverse-effects tests developed by the EPA and modified by SAI and this cause-or-contribute test at 50,000 miles permit an overall appraisal of the effects of HiTEC 3000. No adverse effect is seen for either CO or NO_x in any of the applied tests. One adverse effect is detected for HC: an initial small increase of 0.017 g/mi from 1,000 to 5,000 miles. No additional adverse effect from the use of HiTEC 3000 is seen after 5,000 miles. Finally, the effect seen between 1,000 miles and 5,000 miles has no impact on the ability of a vehicle fueled with HiTEC 3000 to meet applicable emission standards, as confirmed in the cause or contribute test.

NON-REGRESSION ADVERSE-EFFECTS TEST RESULTS ON 75,000 MILE DATA

The availability of 75,000 miles of accumulated data allowed for a much more detailed and long-term analysis of the effects of HiTEC 3000. The EPA tests can be applied, with modifications, to the 75,000-mile data, to test for any adverse effects. The results of the non-regression adverse-effects tests on the 75,000 mile data are summarized in Table 4-13. Data set ETHYL4S2 was again used as the main working set. Since no changes occurred in the initial mileage data, the initial mileage test and the 1K versus 5K test were not run again.

TABLE 4-13. Statistical analysis of 75,000 mile emissions data: results of nonregression adverse test effects. The table notes passes (P) and failures (F) for both EPA nonparametric (NPARM) and SAI parametric (PARM) tests.

Test and Version	HC NPARM	HC PARM	CO NPARM	CO PARM	NOx NPARM	NOx PARM
1k versus 75k						
Equal car means	F	F	P	P	P	P
Unequal car means	P	F	P	P	P	P
Integrated emissions						
1k to 75k	F	F	P	P	P	P
5k to 75k	P	P	P	P	P	P

1K Versus 75K Test

This test is identical in design to both the 1K versus 5K and 1K versus 50K tests. The change in average emissions from 1,000 miles to 75,000 miles is calculated and the resultant values for each fuel type are compared. The statistical test results shown in Table 4-14 and fully detailed in Attachment E (pages E1-E6) indicate no adverse effect for either CO or NO_x, but a small statistically significant increase in emissions between 1,000 and 75,000 miles for HC. Since this test is based on only two mileage points, and since the 75,000 mile averages are much more variable because of effects on emission rates of component changes at 50,000 miles, an alternate test was performed.

The 1K versus 75K test was performed on data set ETHYL4S3, which has adjustments for component change effects (described in Attachment G). In this case there was no significant difference in the emissions change from 1,000 miles to 75,000 miles for HC, CO, and NO_x (Attachment E, pages E7-E12); the calculated HiTEC 3000 effects are shown in Table 4-14. The implication is that the effect seen in the 1K versus 75K HC test based on the working data set (ETHYL4S2) is attributed to component changes and not to HiTEC 3000. We note that the component changes affect CO comparisons as well. The decrease in emissions from 1,000 to 75,000 miles is 0.36 g/mi without adjustments for component changes, and more than doubles to 0.75 g/mi after adjustment for component changes.

TABLE 4-14. Change in emissions from 1,000 to 75,000 miles (g/mi).

	Howell EEE	HiTEC 3000	HiTEC 3000 Effect
HC	0.167	0.197	+0.03
CO	2.48	2.12	-0.36
NO_x	0.39	0.12	-0.27
After adjustment for the effects of component changes			
HC	0.175	0.180	+0.005
CO	2.54	1.79	-0.75
NO_x	0.39	0.11	-0.28

Integrated Emissions Test

The results obtained in this test (Table 4-15) are identical to those obtained in the 1K to 50K integrated emissions test (Attachment E, pages E13-E15). For CO and NO_x, total integrated emissions are reduced through the use of HiTEC 3000. The short-term (1,000 mile to 5,000 mile) increase in HC of 0.017 g/mi observed in those vehicles fueled with HiTEC 3000 again results in a failure in the 75,000 mile integrated emissions test, where the long-term effect is still 0.017 g/mi.

To further evaluate the short-term effect on HC, this test was run a second time using 5,000 miles as the initial level (Attachment E, pages E16-E18). In this additional test HiTEC 3000 does not show an adverse effect on HC emissions. This confirms the result found earlier in the 5K to 50K integrated emissions test. In other words, the initial effect on HC emissions is seen at 5,000 miles, and no additional adverse HC effect is evident from 5,000 to 75,000 miles. Although two of EPA's adverse-effects tests are failed, there is only one adverse effect.

TABLE 4-15. Integrated emissions above initial levels (g/mi).

	EEE	HiTEC 3000	HiTEC 3000 Effect (g/mi)
From 1,000 to 75,000 miles			
HC	0.128	0.145	+0.017
CO	1.92	1.70	-0.22
NO_x	0.22	0.10	-0.12
From 5,000 to 75,000 miles			
HC	0.111	0.110	-0.001
CO	1.70	1.40	-0.30
NO_x	0.14	0.05	-0.09